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Journal of Experimental Psychology

EDITED BY

MADISON BENTLEY, CORNELL UNIVERSITY

HOWARD C. WARREN, PRINCETON UNIVERSITY (*Review*)
RAYMOND DODGE, YALE UNIVERSITY (*Monographs*)
S. W. FERNBERGER, UNIVERSITY OF PENNSYLVANIA (*Bulletin*)
WALTER S. HUNTER, CLARK UNIVERSITY (*Index*)
HERBERT S. LANGFELD, PRINCETON UNIVERSITY, Business Editor

CONTENTS

The Judgment of Facial Expression: J. FROIS-WITTMANN 113

Further Studies in Overlearning: WM. C. F. KRUEGER 152

The Retention and Recognition of Patterns in Maze Learning: THURMAN C. SCOTT 164

The Experiential Fusion of Warmth and Cold in Heat: ALICE H. SULLIVAN AND D. JOSEPH VERDA 208

The New Psychological Laboratory at North Carolina: J. F. DASHIELL 217

A Correction 220

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THE JUDGMENT OF FACIAL EXPRESSION

BY J. FROIS-WITTMANN

Princeton University

The expressions of the human face have been studied from early times. Aside from the alleged 'science' of physiognomy, two principal methods of approach may be recognized in the study of facial expression in the emotions. The first method, of which Bell,[1] Piderit,[2] and Duchenne [3] were the pioneer exponents, consists in the description of the expressions which are assumed to correspond to specific emotions, the study of the muscles which are involved in these expressions, and the explanation of the causes that may underlie the participation of particular muscles in a given expression. It remained for Darwin [4] to give the first complete systematic presentation of the subject. The works of Schultze,[5] Krukenberg,[6] Crile,[7] and Allport [8] may be mentioned in recent times, as well as the experiments and critical conclusions of Dumas [9] and Landis.[10]

[1] Charles Bell, The anatomy and philosophy of expression, 1st ed., 1806.

[2] Th. Piderit, Mimik und physiognomik, 1st ed., 1867 (preceded by a smaller work in 1858).

[3] Duchenne de Boulogne, Le mécanisme de la physionomie humaine, 1st ed., 1862.

[4] Ch. Darwin, Expression of the emotions in man and animals, 1st ed., 1872.

[5] R. Schultze, Experimental psychology and pedagogy (Pintner, tr.), 1912.

[6] A. H. Krukenberg, Der Gesichtsausdruck des Menschen, 1913.

[7] G. W. Crile, Man; an adaptive mechanism, 1916.

[8] F. H. Allport, Social psychology, 1924.

[9] G. Dumas, L'Expression des emotions (in *Traité de psychologie*), 1923.

[10] C. Landis, Studies in emotional reactions: 1. A preliminary study of facial expression, this JOURNAL, 1924, 7, 325–341; 2. General behavior and facial expression, *ibid.*, 1924, 7, 447–511; The interpretation of facial expression in emotion, *J. Gen. Psychol.*, 1929, 2, 59–71.

The second method (to which the present experiment is directly related) consists in the examination of judgments of expression made by observers. Such studies with controlled conditions are relatively recent. The pioneer work in this field is that of Feleky,[11] who posed for various expressions and offered for judgment the photographs thus obtained, "to show what emotional states certain facial expressions do signify." She found that certain expressions were readily identified, while in the case of others characteristic confusions existed. Langfeld [12] and Allport [13] experimented along the same lines with pictures chosen from the Rudolph collection. Langfeld added a study of introspective reports to ascertain the methods used by the *O*s in judging expression, and a study of the effects of suggestion upon the formation of the judgments. Ruckmick [14] experimented with pictures of a female face in the same way as Feleky. He says, in his 'directions,' that he has inquired which of the facial features, the eye or the mouth, gives the best clues for interpretation. Working in another direction, Gates [15] studied group-differences in ability to name facial expression by obtaining judgments from children of various ages, thus determining at what age the expressions become recognized. Boring and Titchener [16] adapted Piderit's 'Geometry of Expression' for demonstrational purposes by using an 'articulated' profile, in which a total expression is obtained from the 'mere addition' of 'given simple expressions . . . often biologically explicable' as pictured in a number of interchangeable eyes, brows, noses, and mouths. Buzby [17] experimented on six of

[11] A. M. Feleky, The expression of the emotions, *Psychol. Rev.*, 1914, 21, 33–41.

[12] H. S. Langfeld, The judgments of emotions from facial expressions, *J. Abn. Psychol.*, 1918, 13, 172–184; Judgment of facial expression and suggestion, *Psychol. Rev.*, 1918, 25, 488–494.

[13] F. H. Allport, *op. cit.*, p. 223.

[14] C. A. Ruckmick, A preliminary study of the emotions, *Psychol. Monog.*, 1921, 30 (no. 136), 30–35; Directions for demonstrating emotional expressions, 1926 (C. H. Stoelting Co., Chicago).

[15] G. S. Gates, An experimental study of the growth of social perception, *J. Educ. Psychol.*, 1923, 14, 449–462.

[16] E. G. Boring & E. B. Titchener, A model for the demonstration of facial expression, *Amer. J. Psychol.*, 1923, 34, 471–485.

[17] D. E. Buzby, The interpretation of facial expression, *Amer. J. Psychol.*, 1924, 35, 602–604.

the typical faces of this model in order to determine the amount of scatter of the judgments, and attempted to analyze the results as to the influence of each of the features. The experiments of Jarden and Fernberger [18] with the same model tested the effect of suggestion on the judgments of the same faces. Finally, Dunlap [19] investigated by means of photographs of male and female subjects the rôle in expression of the eye- and the mouth-muscles.

The Problem

The present experiment was undertaken for the purpose of extending the researches under the second method. It deals likewise with judgments of facial expression as portrayed in a series of photographs and drawings. But its scope is more specific; for the problem, extending in two main directions, has consisted in an attempt to determine objectively, first, the relationship of judgments of facial expressions to each other and to the muscular involvement of the faces, and, secondly, the relationship of the several features of the face to each other, with a view to discovering what factors and principles operate in the differentiation of conventional facial expressions as judged by observers.

The first requisite of this experiment was to have a method as objective and as free from preconceptions as possible. In accordance with our two-fold problem, a two-fold method was evolved.

The first part consisted of a statistical analysis of the judgments and of the muscular involvements.

1. A series of photographs was taken from artificially assumed expressions, since for the purpose of investigating judgments of expression such photographs seemed as adequate as would be those taken of actual emotions. 2. Buzby's test has shown the lack of agreement on some of the Piderit Profile expressions, though they are assumed to be biologically accurate. In order to eliminate the assumption of accuracy of representation the experiment was made independent of the question of 'correctness of recognition.' The pictures were used as mere stimuli, and the expressions were

[18] E. Jarden & S. W. Fernberger, The effect of suggestion on the judgment of facial expression of emotion, *ibid.*, 1926, 37, 565–570.

S. W. Fernberger, Six more Piderit faces, *ibid.*, 1927, 39, 162–166.

[19] K. Dunlap, The rôle of the eye-muscles and mouth-muscles in the expression of emotions, *Genet. Psychol. Monog.*, 1927, 2, 197–233.

allowed to be defined solely by the agreement of observers. To emphasize this objective character, the term Judged Expression (JE) has been applied throughout the experiment to the expressions as observed. 3. The relationship existing between all the various expressive terms used by the *Os* was determined statistically on the basis of the groupings thus obtained. 4. All the pictures were analyzed as to the presence of a contraction in the various facial muscles, for which the term Muscular Involvement (MI) has been used. Thus the MIs of a certain group of JEs could be classified and compared with those of another group. By means of this analysis of the MIs one is able to explain with some accuracy the basis for the judgments.

The second part of the method comprised an analysis of the separate features of the pictures.

5. The individual features of the photographs were isolated as suggested by Ruckmick in his 'directions' and offered separately for judgment. This made it possible to compare the JEs of the eyes and of the mouth with the JEs of the whole face, and to determine the correspondence of the features within a certain related group of faces. 6. Finally the reverse technique (suggested by the Piderit Profile) was developed: several separate features were drawn and offered individually for judgment; then, from their more or less random compounding, a series of composite pictures of expression was obtained and also offered for judgment. Thus a test was made of the assumption of Piderit and others that only given parts, the meaning of which is theoretically determined, can combine into an expression which is equal to the sum of their meanings.

The Experiment[20]

A. *Stimuli.* The two series of pictures of expression, photographs, and composite drawings were made.

The first historical attempts at a systematic pictorial presentation of the various expressions were in the form of drawings, most of which, however, are not free from various inconveniences. Piderit's pictures are theoretical, awkward and schematic. The Boring and Titchener model has the same defects. Rudolph's drawings (used by Langfeld and Allport), although lifelike, are awkward in the case of many of the expressions; also the hair, moustache and beard prevent the perception of the facial musculature. In order to remedy the limitations of previous drawings, two series of photographs were made, by Feleky and Ruckmick respectively, both of which are of a female face. Feleky's pictures are too characterized: the face itself is an individually distinct face (a slight frown, a slight pout are present when in repose); the subject appears in various dresses, the head is seen in different positions, the hand is occasionally used as an expressive aid. Ruckmick's photographs are better standardized: the dress has been replaced by a black drapery, the face is nearer to the average, the hand has disappeared. The head, however, is still seen in various positions.

Photographs. The present series of photographs is of a male face. A few improvements were attempted. The face is fairly neutral; there is no indication of clothes, the hair is

[20] This experiment was conducted in the Psychological Laboratory of Princeton University. Grateful acknowledgments are made to Professors H. S. Langfeld and W. S. Hulin and Dr. H. Schlosberg for their assistance.

without parting and unobtrusive; the face is clean-shaven and its muscles are thus plainly visible; the head has been kept in a uniform three-quarter position, and only that amount of tilting necessary for certain expressions is present.

The experimenter himself posed for the pictures, either assuming the expressions which were most natural to him or imitating those of previous models which had already given good results or seemed to present some special problem.[21] The expressions were in all cases voluntarily assumed. The experimenter practiced before a mirror and when he was satisfied with his expression, snapped his fingers and the picture was taken.

About 120 photographs were obtained, from which, after a trial experiment with 10 observers, only 46 were retained for further judgments on the whole face, the eyes and the mouth.

Composite drawings. An experimental variation of feature-combinations could be done by way of photographs (as in the case of the puzzle pictures of celebrities), provided features of the same dimension and with no foreshortening could be obtained.[22] This was tried without much success, because of the difficulty of having several photographs of exactly similar light and shade; also, the very life-like nature of photographs makes arbitrarily assembled combinations

[21] Of course a woman would copy a woman's expressions more readily than would a man. But this does not mean that a man cannot assume them. On the contrary, this is made possible by the plasticity of the facial musculature and the imitative capacity of the subject, which depends for a great part on the ease with which he can identify himself with a woman and assume the feminine attitude (as exemplified by impersonators). As a matter of fact, a feminine expression like Coyness was frequently judged. This attempt at imitating expressions had an interesting bearing on the question of the *learning of a new voluntary movement*: in practicing a certain contraction of the brow the subject (as was the case in the well-known Ear-Training Experiment), started with somewhat random contractions of the brow and nose until, out of these, he became aware of the existence and locality of a certain postural combination. With more practice the excess movements dropped out and the proper combination became so fixed as a new entity that he could now control it voluntarily in isolation from the contractions originally associated with it. He later learned how to control individually each side of the brow.

[22] Dunlap used this method (*Genet. Psychol. Monog.*, 1927); but his experiment was very limited in scope and so he could afford to have some poor fittings; his way of compounding was also much simpler than ours (*cf.* infra Part II, Sect. C).

seem particularly unreal. Although the use of composite photographs is possible, one can overlook certain distortions better in drawings, and interchangeable drawings are easier to produce. Even with their peculiar limitations they have advantages over photographs, *e.g.*, a greater clarity of outline, sometimes blurred in the photographs, and the elimination of the foreshortening which together create, in the individually presented features of the photographs, an illusion of tilting of the head, thus giving a clue to the expression of the whole face. For these various reasons drawings were adopted in the present experiment. But the drawing ought to be a good substitute, *i.e.*, be detailed enough to resemble a photograph as much as possible. From this point of view the Piderit Profile is so abstract and static that, although the combinations are meant to be 'biologically correct,' in many of them the nose or eyelids are unchanged by the violent action of other features.

The present drawings are a compromise between the Piderit Profile and photographs. In order to insure a more life-like representation than in the Piderit Profile, the number of individual features is greater: 20 eyes, 18 mouths, 8 noses, making the total number of pieces 46. The features are slightly shaded and the head, as in the photographs, is in a three-quarter position.

The experimenter made the drawings and used his own face as a model. The faces were either drawn as a whole from which the features were then cut out, or else the features were drawn individually. The muscular contractions were freely copied from the faces already existing in the various series. The face was divided by horizontal sections into three parts: eyes, eyebrows and forehead; nose and cheeks; mouth and chin. The size of the completed head is 4 x 3½ inches.

All the possible combinations were too numerous to be tested. Instead, the combinations were arbitrarily selected with a view to testing the effect of crossing all the most important eyes against all the most important mouths. Some faces were natural and resembled rather closely the best photographs. Others looked almost like grimaces. The *O*s were warned of this at the beginning of the experimental session, but told that a judgment was nevertheless expected of them.

In putting the parts together, the procedure of simple juxtaposition used with the Piderit Profile could not be adopted, as many of them required too fine an adjust-

ment. The absence of foreshortening in the individual features, for instance, carries a defect for the whole face which must be remedied by a slight *slanting* of the parts, just as a corresponding correction in the reverse direction was made in the case of the features abstracted from the photographs.[23] A very simple procedure was used: either the drawings of the features were slanted as was required, and then the combinations were photographed, or photostatic reproductions of the features were first obtained, which were then glued on a card at the desired angle. Both methods gave equally good results, insuring standardized, constant stimuli for the judgments.

In previous investigations the brow, the eyes, the nose, and the mouth have been presented in isolation for judgment. In the present experiment the following features were shown: 1. the brow and the eyes together, which, in the course of this work will be called the eyes; 2. the mouth, which was presented alone in the photographs, and together with the chin in the drawings. The nose was not judged in connection with either the eyes or the mouth. It was only presented in the whole faces, and was changed now and then to help harmonize the contractions of the eyes and of the mouth. Sometimes a blank space was left in the place of the nose, and the results were practically the same.

There were 59 composite drawings presented for judgment. The total number of stimuli was 227 pictures and fragments of pictures, distributed as follows: whole faces: photographs, 46; drawings, 59; eyes and mouths: photographs, 84; drawings, 38.

B. *Observers. Presentation of the stimuli.* The observers were college students. The same group was not always available; there were three groups of 15, 30 and 120 *O*s respectively. As, on the other hand, not more than 25 pictures could be presented at each session, it was not feasible for all of the pictures to be judged by the same *O*s.

For the presentation of the separate features of the photographs, the face was hidden by a piece of light cardboard, about the size of the whole picture, in which rectangular openings allowed either the eyes and brow, or the mouth, to be exposed.

The whole faces were exposed for a short period; from 5 to 30 seconds. The separate features were exposed somewhat longer on account of their smallness and relative indistinctness.

The whole faces were not presented in the same session with the separate features, except when pressed for time, in which case all the features were presented first, so that the

[23] A face composed of the *same* features was judged alternately as Sadness and as Disdain, according to whether the parts were slightly slanted or not.

previous perception of the whole face could not influence that of the features. The features and the whole faces were always presented in random order. The observers were also required to use different sheets to write their judgments for the eyes, the mouth, and the whole.

For the purpose of restricting *O*'s choice of words, as well as to obviate so far as possible inequalities in their vocabularies, each *O* was given a mimeographed list of 43 terms, which had been compiled from Feleky and other authors.

Treatment of the Data: Results

The data consisted of the judgments given in response to the 227 stimuli (drawings and photographs of whole faces, eyes, and mouths). There were from 15 to 143 judgments on each picture. A total of 11,965 judgments was obtained.

A. Analysis of the Judged Expressions

Grouping of the judgments. First, the various judgments were tabulated for each separate picture.[24] It was found that the same type of distribution occurred as was present in the tables published by Feleky and Buzby; namely, there was both a wide scatter and one or several points of high frequency. The mode indicated the amount of agreement on a particular JE for each picture. Langfeld states in his report that "50% acceptance indicates a successful portrayal of the expression." The median for the agreement on all pictures in the present experiment is 37.5%. Considering, however, that our figures refer to single expressive terms, while most previous investigators gave partial credits for 'approximate names,' the mode for our pictures is higher than that for the pictures used in the former studies.

Secondly, the number of terms used in the judgments for all the pictures totaled 122 words.[25] A reduction of the total

[24] When an *O* used more than one term for a picture, they were separated, as was done by Feleky, into the respective expressions. The terms indicating a complex expression (*e.g.*, Amused Surprise, Malicious Laughter, etc.) were eliminated.

[25] The range of 122 descriptive terms (among which were such unclassifiable circumlocutions as "Oh! Boy!," "Tough Luck," etc.) is, of course, considerably greater than the list proposed to the *O*s, the 43 words of which were thought sufficient.

number of terms was made for the sake of simplicity by omitting all the terms which occurred only one, two, or three times. This left a total of 38 terms.

Thirdly, all the pictures for which the same term occurred in highest frequency, *i.e.*, as the mode, were grouped together. Only 32 terms (out of the 38) appeared as modal frequencies. Thus all the pictures were divided into 32 groups.

In each group of pictures averages were obtained for the modes, and also for each of the other terms which had been given less frequently. For example, the term Anger occurred as the mode for five pictures. These five pictures form one group. The five frequencies given for Anger have an average value of 39%. The average of the other terms used for these five pictures are: Contempt, 5%; Disgust, 2%; Hate, 20%; Rage, 5%; Fear, 4%; Anxiety, 2%; Dismay, 5%.[26]

Table I presents the average values of the terms given for each of the 32 groups. In the left-hand column are listed vertically the modal JEs according to which the pictures were grouped. Across the top of the table are listed horizontally the 38 expressive terms. By reading across one may find the average frequency (in percentage) of any term for the group of pictures of which the JE on the left is the mode. The modal average frequencies themselves are printed in heavier type. Thus one may read down the column at the left to Anger, then by reading across horizontally the pictures of which Anger is the mode appear. The order of terms in the left-hand column is an approximate representation of the closeness that exists between various points of high frequency, as shown in the next section.

These 32 modal JEs were chosen as the expressions to be studied in detail throughout the work. It is noticeable that

Similarly Feleky's subjects used 147 words in their reports, though her list contained an ample choice of 110 words. The adequacy of a restricted number of terms to describe pictures of expression seems to be proved, however, by the fact that in the present experiment the proposed list was accepted by a great majority of *O*s.

[26] The terms, the average value of which in all the pictures of a group was less than 2%, were discarded in order to avoid undue complexity. Thus the sum of percentages is generally less than 100. Because of these various simplifications no weighting or measurements of reliability were made.

TABLE I

AVERAGE PERCENTAGES OF ALL JUDGMENTS FOR EACH JUDGED EXPRESSION OCCURRING AS A MODE

Modal Judged Expressions	Descriptive Terms	Laughter	Pleasure	Gloating	Superiority	Disdain	Cynicism	Aversion	Sulkiness	Contempt	Disgust	Sneering	Hate	Anger	Rage	Determination	Horror	Fear	Surprise	Anxiety	Interest	Attention	Reflection	Bewilderment	Doubt	Disappointment	Sadness	Crying	Pain	Effort	Grief	Appeal	Coyness	Admiration	Amazement	Dismay	Distrust	Inferiority	Stubbornness	Number of Pictures	Number of Judgments
Laughter		55	21	4									3	3															3										11	768
Pleasure		9	50	2	5							2							3		2												2							9	385
Gloating		5	10	43	14						2		3		10			2						2																2	116
Superiority			4	3	37	4	3			10			3						3		4	2			2								3							13	740
Disdain				.	31	48	5			11																					3									1	112
Cynicism				7	25		29			21																														1	28
Aversion							16	23		16	6									6					6												10			1	31
Sulkiness					3				28	10	5					5							3		9		9										5	9	274
Contempt				3	5			2	3	35	15	2	3	3									2				3		2								2	2	15	747
Disgust							2		2	19	32	5	10	4			2									2			5										12	521
Sneering								2		16	19	38	10			4		2										2										3	174
Hate											4		35	26	5	5		4		2															5			3	82
Anger										5	2		20	39	5		4	4						2				3	2							2			5	320
Rage										3	5		11	7	44	2	7	5					3	2															10	623
Determination									3	3	2		6	6	3	42						2	3	4				3									3	4	13	795
Horror											2			3	7		47	16	5									4										13	711
Fear														4			10	29	14	8				9		2	2							5				5	317
Surprise																	2	6	41	3	2	2		9	2									5	6			23	1,121
Anxiety														2			3	5	13	27		6	4	9	10	5								5	6			5	224
Interest																			10		39	11	2		8							8				5		4	433
Attention			4							2						4			3			45	7		11		2											3	77
Reflection					4				4	2	2			2		4		2	3	2	2	4	32	11	5				2								2	3	5	67
Bewilderment		2								2	6	2	4	3				3	12	5		2	2	33	9	2	4						4		2				4	179
Doubt					9					7	2					4			7				6	7	30	5	2			3	2						4	7	551
Disappointment					2						2					2				2		2	5	4	13	25	16				7		2			3			2	77
Sadness				2	3					7	5									3			2	2		12	32	7	2			2			2				10	411
Crying				2						2			2				6									3	3	52	7		9								9	467
Pain								2		2	3		2	3	2	4	4	2								3	2	5	39	9	9	3							10	553
Effort																													28	68									1	25
Grief								3												3				3	2	4		9	18		35	5							8	529
Appeal					5																	2					8		7		32	36					4		1	99
Coyness			5	10	4		2											2					3								9	38	2						9	406
																															Total Number of Pictures							227	
																															Total Number of Judgments								11,965

only two of these, Cynicism and Disdain, concerned terms not included in the original list proposed to the *O*s.

Relationship of the judged expressions. It will be seen that beside the mode there are a few high secondary frequencies within each group. The next problem was to determine what significant relations existed between the 32 modal JEs and their secondary frequencies.

The simplest procedure was to find what percentage each of the JEs occurring as a high secondary frequency was of the JE occurring as the mode; then conversely to find what percentage the latter JE (as a secondary frequency) was of each of the former JEs when they occurred as modes. A quotient stated in percentages was obtained in each case by dividing one frequency by the other. This percentage indicates the frequency of concurrence of one JE with the mode of another. The average of the two quotients represents the degree of concurrence of the two JEs compared.

For example, when Anger occurred as a mode and Hate as a secondary frequency the quotient was 51%. When Hate occurred as a mode and Anger as a secondary frequency the quotient was 64%. The average of these two quotients is 58. Similarly when Determination occurred as a mode and Anger as a secondary frequency the quotient was 14%. When Anger was the mode Determination did not occur as a secondary frequency. The average is therefore 7.

The relations of these quotients are graphically represented in Chart I. Two JEs were linked together when at least one of them occurred as the secondary frequency when the other was the mode. One member of a pair could thus be connected with one or several JEs, *i.e.*, one JE could be a member of several pairs. Each expression in a pair stands in a double relation with the other; as the mode of a distribution where the other is a secondary frequency, and as a secondary frequency in a distribution where the other is the mode. The numbers in the small squares express in percentage the relation of a secondary frequency to a mode. The arrows point to the expression that stands as mode in the relationship. The third number is the average of the two percentages expressing the degree of concurrence. The pairs with the greatest degree of concurrence were listed one

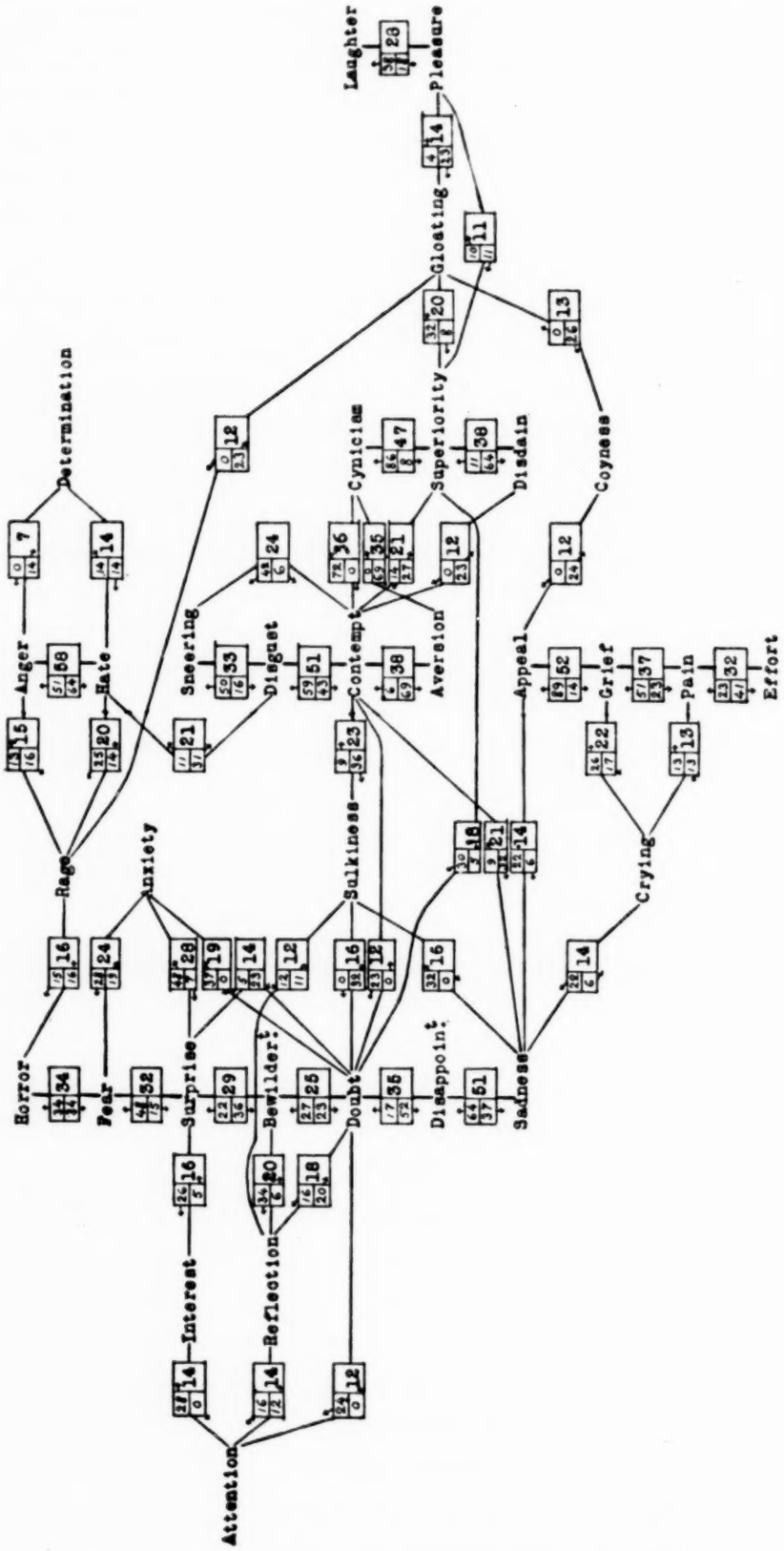


CHART I. Relationship of 32 judged expressions based on their frequencies of concurrence.

under the other on a vertical line. The other JEs were connected laterally. No value for a vertical connection is smaller than a value for the *next* lateral one, and *vice versa.*

For instance, Disgust and Hate (with a value of 21) are linked laterally because Disgust is linked vertically to Sneer and Contempt with higher values. In consequence of the lateral connection of Disgust and Hate, the next pair, Hate and Rage (with a smaller value), must be linked laterally; and the next pair, Rage and Horror (with a still smaller value), must also be linked laterally. Only when we come to the pair Horror and Fear can the connection be vertical, because the value is higher than the preceding lateral one.

In Chart I there are six sets of vertically linked JEs. Five of them (Anger-Hate, from Sneering to Aversion, from Cynicism to Disdain, from Appeal to Effort, and Laughter-Pleasure) correspond broadly to the classic groups of expressions; the sixth, from Horror to Sadness, does not correspond quite so well. The six vertical sets themselves can be enlarged into broader aggregates by including into them some of the laterally connected JEs, either because of the strength of the connection, as in the case of Cynicism with Contempt and Aversion, or because of the lack of connections with other sets, as in the case of Determination, which is only linked to Anger and Hate.

Neither these sets, however, nor the order of the grouping should be thought of as the only possible ones, for a lateral connection may be almost as high as the next vertical, and vertical connections in one set may be smaller than lateral connections in other sets; also each set communicates with the one next to itself, and with one or several others. In short an outstanding feature suggested by Chart I is the many relations between the various JEs.

Types of concurrence. In Chart I it may be seen, further, that the relation between the two percentages varies widely from pair to pair. It was possible to list as follows the main relationships of the 32 JEs in respect to three types of concurrence.

(a) In the case of 4 pairs, the concurrence is reciprocal; *i.e.*, when each JE of the pair occurred as the mode the frequency of the other was at least 25% of the mode:

Modes	Secondary Frequencies (at least 25% of the mode)
Hate	Anger
Anger	Hate

Disappointment	Sadness (and Doubt)
Sadness	Disappointment (and Contempt)
Disgust	Contempt (and Hate)
Contempt	Disgust
Horror	Fear
Fear	Horror (and Surprise and Anxiety)

Such "characteristic confusions" have been generally mentioned in previous experiments.

(b) In 10 cases one JE seems to be subordinate to another; *i.e.*, one JE did not occur as mode without the occurrence of another JE with a percentage of at least 25%, while the latter JE occurred as mode more or less independently of the occurrence of the former:

Modes	Secondary Frequencies (at least 25% of the mode)
Appeal	Grief
Disdain	Superiority
Effort	Pain
Laughter	Pleasure
Reflection	Bewilderment
Gloating	Superiority
Doubt	Superiority
Coyness	Gloating
Rage	Hate
Superiority	Contempt

(c) In 8 cases one JE seems to be subordinate to two or more others, *i.e.*, one JE did not occur as mode without the occurrence of two or more other JEs with percentages of at least 25%, while the latter JEs occurred as modes more or less independently of the occurrence of the former:

Modes	Secondary Frequencies (at least 25% of the mode)
Cynicism	Superiority and Contempt
Aversion	Contempt and Cynicism
Sneering	Disgust and Contempt
Anxiety	Surprise and Doubt
Sulkiness	Contempt, Doubt and Sadness
Grief	Pain and Crying
Bewilderment	Surprise and Doubt
Interest	Attention and Surprise

Finally, the remaining 6 JEs occurred as modes together with various secondary frequencies; but the latter were always less than 25% of the mode. These 6 JEs are

Pain
Surprise
Attention
Crying
Determination
Pleasure

Never was a JE so universally agreed upon as to occur without any significant secondary frequencies. The reader is referred to Chart I for the position and context of the related JEs.

Hierarchy of specificity of the judged expressions. An inspection of the just mentioned relationships of the JEs reveals the existence of a double tendency in expressions; the tendency of a JE to occur as a mode with other JEs present in the same distribution, and its tendency to be present in distributions where other JEs are the modes. Thus it appeared that all the JEs of Chart I could be compared and ranked in respect to this double character.

For instance, Coyness and Aversion never occurred as modes without other concomitant judgments of other expressions, but were themselves never or rarely found in the other distributions. In a reverse manner, Contempt and Superiority were reported by the *O*s in connection with 9 and 6 expressions respectively, while few other expressions were reported when they were the modes. Doubt illustrates the case of a JE occurring in connection with several JEs in distributions where it was the mode as well as in other distributions.

If to this double character the value of the mode, which is a positive indication of the specificity of a JE, is added for comparison, then a fairly complete hierarchy of specificity of the 32 JEs can be established. High specificity means a JE of high mode which is accompanied by low secondary frequencies and of low participation in other distributions.

Such a grouping was made in Table II, on the basis of the mode, after the JEs had been ranked in respect to their mode, their inclusion of other frequencies and their participation in other distributions, and after the lower and upper Quarters and middle Half of the rank order had been determined in each case.

The general lack of specificity of most expressions can be seen from the tables; only Laughter is highly specific (high mode, low in columns II and III). Next to it come Crying, Horror, etc., which have a high mode and low secondary

frequencies, but are frequently used in describing the various pictures. The other JEs can be interpreted in similar fashion.

TABLE II

HIERARCHY OF 32 JUDGED EXPRESSIONS BASED ON THEIR MODE, THE PARTICIPATION OF SECONDARY FREQUENCIES IN THEIR DISTRIBUTION, AND THEIR PARTICIPATION IN OTHER DISTRIBUTIONS

(I) Mode	(II) Participation of Secondary Frequencies	(III) Participation in Other Distributions	32 Judged Expressions
High	Low	Low	Laughter
"	"	Med	Crying, Horror, Pleasure, Effort, Attention
"	Med	Low	Disdain
"	"	Med	Rage
Med	Low	Low	Determination, Coyness
"	Med	"	Interest, Sneering
"	"	Med	Gloating, Anger, Pain, Bewilderment
"	"	High	Superiority, Grief, Contempt, Surprise, Hate, Sadness
"	High	Med	Appeal
"	"	High	Disgust
Low	Med	Med	Reflection, Anxiety
"	High	Low	Sulkiness, Aversion
"	High	Med	Fear, Disappointment, Cynicism
"	"	High	Doubt

The results obtained by the analysis of the judgments are as follows. The interrelationships of the 32 previously unconnected JEs on the basis of their tendency to occur concurrently in the judgments; the types of concurrence in the related JEs; their hierarchy in respect to the agreement of the *O*s, and to the extent to which other expressions were concurrently reported when they were the modes, or to which they were reported when other expressions were the modes.

B. Analysis of the Muscular Involvements

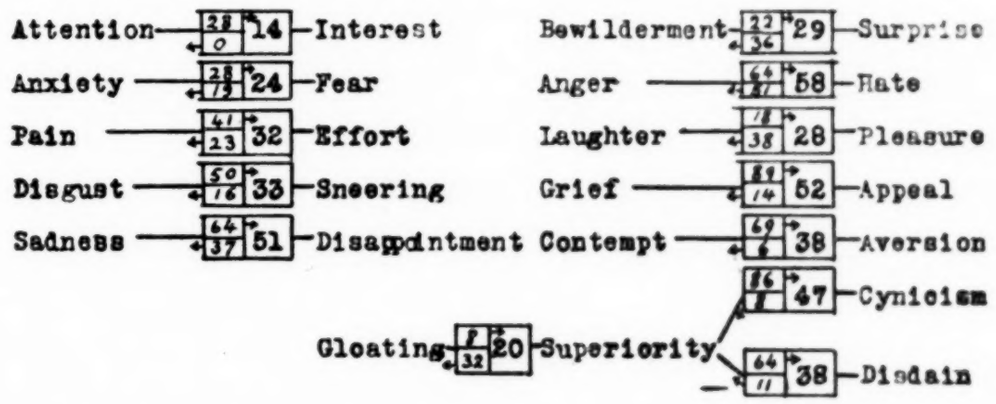
An analysis of the stimuli was next sought with a view to examining what in the muscular involvements of the faces made possible the JEs obtained on them. The first consideration was to determine whether any specific muscular involvement (MI), combination of MIs, or pattern, characterized each of the 32 groups of pictures.

Tabulation of the muscular involvements. An accurate measurement of the muscular contractions in pictures is practically impossible, due to the irregular size and shape of the muscles, their being covered with skin, the various fore-

shortenings of the head, etc. We therefore followed Landis's procedure of determining the presence or absence of each type of muscular contraction for all the pictures or fragments of pictures, then of obtaining the percentages of frequency of occurrence for each of the MIs concerned in each JE.[27] These percentages, obtained with reference to 28 possible positions of the facial muscles and head, are given in Table III.[28]

In Table III the 32 JEs were used as class-intervals for the tabulation of all the MIs for the various pictures. The separate listing of each JE, however, could not be strictly maintained, for the pictures of a group were in some cases so few in number that an average of their MIs would have resulted in practically 100% or 0 frequency, whereas with more numerous pictures the frequencies would approach a more normal distribution. Therefore, when the pictures of a given JE were too few, that JE was averaged together with one or more JEs with which it was most closely related in Chart I. In view of the fact that several class-intervals contain more than one JE, they have been called 'JE-groupings.'

The groupings of JEs which seemed practical in order to obtain significant averages of MIs include the following:[29]



[27] Any degree of contraction, whether slight or extreme, constituted the presence of an MI.

[28] In order to make the MI values more significant, some of the pictures used by Feleky, Gates and Buzby (the modal judgments for which were fairly high in the tables published by these experimenters) were included in their respective JE-groups. Thus the number of pictures used in the making of Table III is slightly higher than in Table I.

[29] There is only one exception: the MIs of Anxiety were so dissimilar to those of Surprise, and so similar to those of Fear, that they were, *a priori*, averaged with the latter, although the relationship of the JEs in Chart I is slightly lower than that of Anxiety and Surprise.

TABLE III

PERCENTAGE OF FREQUENCY OF VARIOUS MUSCULAR INVOLVEMENTS FOR EACH GROUPING OF EXPRESSIONS

		Attention Interest	Bewilderment Surprise	Horror	Anxiety Fear	Rage	Anger Hate	Pain Effort	Crying	Laughter Pleasure	Coyness	Disgust Sneering	Grief Appeal	Sadness Disappointment	Determination	Reflection	Doubt	Contempt Aversion	Sulkiness	Superiority, Disdain Cynicism, Gloating	Average	M.V.	P.E.
Brow	frowning	33	23	58	92	100	100	90	80	33	0	75	100	100	100	100	0	43		43	65	31.9	27.0
	raised	11	64	100	83	50	14	80	60	14	0	42	78	88	0	0	100	28		50	48	30.4	25.7
Upper lid	raised	89	91	100	92	100	100	20	0	13	67	42	11	38	90	50	0	29		14	53	34.3	29.0
	depressed	11	9	0	8	0	0	70	100	87	22	59	56	51	10	50	100	71		64	43	31.2	26.4
Lower lid	wrinkled	33	32	50	0	100	86	90	100	100	89	100	67	0	60	50	0	71		64	61	28.9	24.4
	wrinkled	0	0	33	0	100*	50	42	0	20	0	40	17	0	57	0	0	21		10	22	22.8	19.3
Nose	pinched	0	0	22	25	17	25	67	100*	0	0	50	83	20	57	0	0	27		0	27	24.3	20.5
	dilated	0	8	56	17	100	75	78	75	90	50	80	50	40	0	0	0	64	No Eyes or Noses	70	47	29.7	25.1
Lips	open	60	100	100	100	100	83	83	88	82	60	50	50	30	27	0	0	29	11	14	56	31.2	26.4
	closed	40	0	0	0	0	17	17	25	18	40	50	67	70	91	100	100	80	89	86	46	33.8	28.6
Teeth	open	40	95	100	92	38	50	58	50	59	60	6	33	10	0	0	0	7	11	7	38	27.9	23.6
	closed	40	4	0	8	63	50	42	50	41	40	94	67	90	100	100	100	93	89	93	61	29.1	24.6
Teeth exposed	upper	20	13	75	17	75	67	83	75	76	20	47	33	20	0	0	0	21	0	14	35	27.1	22.9
	lower	0	21	75	25	100*	83	58	13	59	0	12	17	0	9	0	0	0	0	7	25	26.1	22.1
Upper lip	raised	20	0	67	17	75	83	92	63	76	20	100	0	30	45	33	33	93	0	57	48	29.3	24.8
	depressed	0	61	17	33	25	17	8	38	0	20	0	50	0	45	0	50	0	33	0	21	17.7	15.0
	protruding	0	30	33	0	0	0	25	0	0	40	24	0	10	18	67*	17	13	33	14	17	14.1	11.9
Lower lip	raised	0	0	17	8	0	17	25	100	0	20	76	67	30	81	33	83	80	44	50	39	28.8	24.3
	depressed	0	0	58	8	100	83	67	88	65	0	24	33	20	9	0	0	27	0	14	31	28.8	24.3
	protruding	20	34	8	8	0	17	25	13	0	40	65	33	70	36	100	67	67	78	57	39	24.6	20.8
Corners	raised	0	13	0	8	0	0	0	13	82*	80*	6	0	0	9	0	33	7	0	36	15	17.9	15.1
	retracted	0	4	42	8	75	67	33	88	94	40	12	50	0	63	0	50	20	33	43	38	24.4	20.6
	depressed	20	13	17	25	88	50	67	75	0	0	71	100	80	91	67	67	67	78	57	54	27.0	22.8
Chin raised		0	0	17	8	0	17	25	100	12	0	76	67	40	87	100	100	80	89	43	44	33.4	28.2
Glance	side	44									89									43			
	down										56									86			
Lips retracted									63				33		63								
Head back																				83			
Number of pictures		9	32	15	12	10	9	13	9	22	10	19	9	13	14	5	7	18	9	18			

* The numbers indicated by asterisks deviate from the averages of the measures by three times the P.E.

The MIs for the various JE-groupings are presented in Table III in the following manner. In the left-hand column are shown the MIs. In the horizontal line across the top of the table are listed the JE-groupings.

By reading across the table one may find the frequency of occurrence (in percentage) of any MI for any JE-grouping. Thus one finds that the frequency of the frowning brow for Rage, Anger, Hate, etc., is 100%, which means that a frown was present in all the pictures judged as Rage, Anger, Hate, etc. By reading down any vertical column one finds the MIs for a given expression. Thus in all the pictures judged as Rage the frequency of occurrence of the raised brow is 50%, of the raised upper lid 100%, etc.

It frequently happens in Table III that the total of the percentages concerning two antagonistic MIs is over 100; though it might be expected that if one MI occurred in 100% of the cases the other would not be found. This is due to the fact that these antagonistic MIs really take place in different muscles or in different parts of the muscle-groups. Such simultaneous contractions are possible in the following muscles; middle part of the frontalis and corrugators (the 'oblique brow' or 'grief-brow' of the literature), outer parts of the frontalis and pyramidalis nasi, compressors and dilators of the nostrils, levator menti and depressors of the lower lip (as in the 'square mouth' of Crying).

Specific and significant involvements. The significance of the frequencies of involvement was next considered. Landis, who was seeking 'a true individual difference' in an expression, only considered significant "any figure which deviated from the average of the figures of which it was one, by three or more times the probable error." The very few figures thus obtained, in his and in the present experiment, when this technique was applied, would indicate that there were but few true individual differences. These figures have been indicated by stars in Table III. The MIs thus obtained will be called 'specific' for the JEs concerned.

Such differentiation of the JE-groupings, however, does not fully characterize each of them, because, based upon differences apparent on the horizontal lines, it does not include all the characteristic MIs for a given grouping, which are shown by the vertical columns. (As an analogy, black hair does not differentiate a Negro from a Chinaman, yet it is a

characteristic of each, a fact which would not appear by using a technique based on the P.E.). All the MIs occurring in at least 80% of the cases were therefore taken as indicating their average tendency to occur in a JE-group, and are called 'significant' for that JE. These figures have been printed in bold face in Table III. The great number of the facial muscles affords endless possibilities for combinations which form characteristic patterns. The combination of specific and significant MIs represents the pattern of a JE-grouping. The patterns for the various groupings can be easily recognized in the vertical columns, and it can be seen that no two patterns are exactly alike.

Factors of differentiation. Two factors, generally present together, can bring about differentiation of one pattern from another:

First, the presence of MIs which are specific or significant for only one JE-grouping or for several closely related groupings; for example, the mouth corners raised in Laughter and Coyness; the pinched nose in Crying; the wrinkled nose in Rage; the exposed lower teeth in Rage and Anger; the protruding lips in Reflection; the exposed upper teeth in Pain; the open mouth in Fear, Horror, Surprise; the closed mouth in the expressions around Contempt; the side glance in Coyness; the glance down and the head back in Superiority.

Secondly, a special combination of two MIs; for example, the raised brow with raised upper eyelid in Horror and Fear; the frowning brow and raised upper eyelid in Rage, Anger, and Determination; the raised brow and depressed upper eyelid in Doubt; the open lips and teeth in expressions around Surprise; the raised upper lip and exposed upper teeth in Pain; the raised upper and lower lips in Contempt; the lower lips raised at the middle and depressed at the sides in Crying.

When such combinations are shared by several groupings, then the superposition of other combinations on them changes the pattern considerably and brings about their differentiation, for example, the raised and frowning brow is common to Fear, Pain, and Sadness; but Fear is differentiated by the raised upper eyelid, which is absent in Pain and Sadness;

Pain, by its special mouth-combination; and Sadness, by the absence of any other involvement except the depressed mouth corners; both eyelids are contracted in Laughter and Crying, but Crying is differentiated by the frown. Similar combinations, simple or of increasing complexity, similarly differentiate all well-agreed-upon expressions and individual faces.

Furthermore, though an MI or combination be common to several expressions, when it appears as the only outstanding one in a certain JE-grouping, it is sufficient to differentiate that expression; for example, the raised upper eyelid, when not entering into any combination, differentiates Attention; the closed teeth with raised upper lip occurs alone only in Disgust and Aversion.

Finally, we may assume that the total number of significant MIs represents the 'total expressiveness' of the pattern, which may have a direct bearing on the mode of the JE; *e.g.*, Laughter, Crying, and Rage have a high total expressiveness and are well agreed upon.

Relations of the patterns. The number of significant involvements common to various JE-groupings does not minimize their significance. On the contrary, they furnish an important means of investigation of the expressions, and afford the basis for a grouping of the latter with reference to their muscular patterns. Thus the position of the groupings in Table III was determined by the number of MIs that were common to two or more groups, as the JEs in Chart I were themselves arranged according to their degree of concurrence. The same graphic representation would have been desirable, but the serial order had to be maintained because the reference of each JE to the various muscles could not be omitted, and in consequence of this serial order the position of some groupings is only approximate.

We can now compare the arrangement in the JE-groupings in Table III with the relationships of Chart I. We find that the position of the groups relative to each other on the basis of the MIs generally agrees with the position of the JEs in Chart I, which means that the greater the degree of concurrence between two JEs the more MIs they have in common, and *vice versa*.

Only 8 expressions have changed their place, due to the number of significant MIs their patterns possess in common with other expressions. They are: *Anxiety*, the eyes for which are identical to those of Fear; *Laughter* (*Pleasure*), which has four MIs in common with Crying and three with Rage; *Coyness*, which has two MIs (out of three) in common with Laughter (Pleasure); *Pain* (*Effort*), which has four MIs in common with *Anger* (*Hate*); *Crying*, which has four MIs in common with Laughter, and four with Rage; *Disgust* (*Sneering*), which does not have more in common with Contempt than with Anger and has been placed between those two expressions; *Determination* and *Reflection*, which have four MIs in common, and generally resemble the patterns around Contempt.

For the relations of three of these eight JEs in Chart I, notwithstanding weak relations in their significant MIs, there is a basis in Table III: The mouth for Disgust, except for the absence of closed lips, is very similar to that of Contempt; they are the only expressions with teeth closed and upper lip raised, and the additional MIs that help to differentiate Contempt are almost as frequently present in Disgust. *Determination*, while its mouth resembles that of Contempt and like expressions, has the eyes in common with Anger (Hate). The glance has some similarity in *Coyness* and in *Gloating*, though it is more to the side in the former expression, and more downward in the latter.

On the other hand, the relationships in Chart I of the five remaining JEs: *Pleasure*, related to Gloating; *Anxiety* to Surprise; *Reflection* to Bewilderment; *Crying* and *Pain* to Grief and Sadness, cannot be so easily explained on the basis of our results. Nor can the lesser degrees of concurrence of several other JEs. This indicates that the relationships among some expressions are different according to whether they are examined in reference to the judgments made on the faces or to the tabulation of the various muscles involved. This is due to the grouping together of all the pictures having the same modal JE, whereby different pictures judged similarly are found in the same JE-grouping, while similar pictures judged differently are found in different JE-groupings. Thus when the JE-groupings were arranged in Table III according to the relations of the MIs, a perfect correspondence with the relationships of the JEs in Chart I could not be expected. This important fact is only one special case of the variability of all the measures concerning the judgments of facial expression.

Variations: Validity of the concept of expressional patterns. It has already been noticed that only six MIs deviate sufficiently from the average to be called specific, while the other MIs extend to a great many groups. This overlapping among the groups is still greater in the case of the JEs.

Thus our results would indicate a position departing from the traditional view (such as expressed by Piderit) that expressions have fixed patterns, or the view (such as expressed by Duchenne) that the *differentia specifica* of each expression consists in the contraction of one special muscle. Yet it has been seen that each JE-grouping is characterized by a particular pattern.

We believe, moreover, that our results with posed expres-

sions resemble results with actual emotional expressions (such as obtained by Landis); although the latter claims that nothing but variability obtains in the case of emotional expressions and that there is no true individual difference between them. That characteristic patterns are evident despite the variability can be demonstrated in the case of four expressions selected from this experimenter's tables and offered in Table IV.

TABLE IV

EVIDENCE OF PATTERNS IN EXPRESSIONS AROUSED BY EMOTIONAL SITUATIONS (MODIFIED FROM C. LANDIS, TABLE II)

	(I) Skin Diseases	(II) Ammonia	(III) Electric Shock	(IV) Rat
Frontalis	15	26	38	25
Corrugators	21	37*	22	29
Upper Orbic. Oc.	51	56	54	64
Lower Orbic. Oc.	77	70	82	78
Nasalis	43	64*	16	41
Quadrates	72	74	73	77
Zygomatics	34	41	58	77
Risorius	26	37	43	79*
Lips open	24	30	73	66
Mentalis	2	11	2	7
Triangularis	28	22	46	25

Although the pictures were grouped in a manner most favorable to reveal the absence of patterns (since the averages were made to include pictures taken before and after the actual stimuli were administered, thereby favoring swamping), fairly definite patterns are visible if frequencies of occurrence of at least 70% are included in addition to his specific frequencies.[30] In group I (situation: looking at pictures of skin diseases), the upper lip is raised, which wrinkles the lower eyelid. This combination is present also in the three other groups, but with important additions: in group II (situation: smelling ammonia), the pinched nose and the frown are specific for that expression; in group III (situation: receiving an electric shock), the lips are open; in group IV (situation: decapitation of a live rat), the corners of the mouth are raised and retracted.[31]

[30] Since Landis's averages were lower than ours, it was necessary to include values from his table which were lower than those chosen in the present experiment, in order to show the figures that were significant for his patterns of muscular involvement.

[31] The pattern in the "Rat" expression exactly corresponds to the pattern of Laughter in Table III, and a broad grin appears on most of the pictures offered by

The results arrived at in the present section can be summarized by the following statements. Despite the variability of the measures, typical patterns occur; they are differentiated from each other by characteristic MIs or combinations. A typical pattern characterizes an expression in a schematic way, *i.e.*, it expresses the central tendency, determined by the most frequently occurring MIs, but does not account for the individual variations, which are considerable.

C. Comparative Analysis of the Features and Whole Faces

Judgments of parts and wholes. It can be seen in Table III that the MIs constituting a pattern were not all present in 100% of the cases, which means that in some of the individual pictures typical MIs may be absent. This suggests the possibility that one MI may be dominant in the characterization of a face while other MIs of the total pattern are missing. Before the dominance of the one MI on the rest of the face can be determined, the effect of the individual MIs on each other should be known. An approach to the solution of this problem was sought in the analysis of the separate features of the faces.

The composition of the patterns as shown in Table III allows the inference that the facial-expression patterns are wholes made up of functional parts (the MIs and their combinations). The function of these parts in influencing the judgments of the whole face can be tested by determining whether each MI signifies an expression, as does the whole

Landis. Nevertheless, he rather naïvely states that "an expression marked by the contraction of the orbic.ocul., the risorius and the zygomatics [produces] an effect to which it is difficult to assign a subjective name. It is a combination of what Darwin calls horror and that which he calls contempt." In so saying, this investigator, who has explained beforehand that such contractions were part of the mechanism of the smile, obeys, as do his *O*s in their reports, the suggestion of the situation. If such statements are discarded as rationalizations due to the task of describing feelings or facial expressions aroused by, and incongruous with, a socially condemned situation, then there are good reasons to admit the Laughter pattern as an expression of suppressed enjoyment (sadism). This view would, at the same time, account for the discrepancy between the introspective reports of the *O*s (Disgust, etc.) and their facial expressions (Laughter pattern), and enable a connection to be established between expression and situation through the medium of an (unintrospectable) emotion consistent with both.

face, and if so, how constant the expressive significance of each MI is in the various patterns into which it enters. Since the MIs cannot be judged individually, the two main groups of MIs, those involving the eyes and those involving the mouth (on which judgments had been previously obtained) were selected for experimentation.

In the preceding tables, the whole pictures and the fragments of pictures had been grouped according to their modal JEs with the result that a face and its separate features often fell in different groups. For the present analysis the whole faces having the same modal JE were grouped together as above, and in addition the judgments of the eyes and the mouth of a face were listed immediately under the judgments of that face irrespective of their own JE. Thus the judgments of the whole faces of a JE-group could be compared with the judgments of the individual features of the same face. The averages for the three sets of judgments, the whole faces (W), eyes (E), and mouths (M), in each group are given in Table V.[32]

Table V shows that there are several types of agreement between the features and the whole face. They are as follows.

1. Two features with the same mode may combine into a face with the same modal JE. This is found in the case of Pleasure, Disgust, Determination, Horror, and Surprise.

2. Two features with the same mode may combine into a face with a different modal JE. This is found in the case of Laughter, Rage, and Bewilderment.

3. Two features with a different mode may combine into a face with the same modal JE as one of the features. The whole face agrees with the eyes in the case of Anger, Fear, Anxiety, Reflection, Doubt, and Grief. The whole face agrees with the mouth in the case of Superiority, Sulkiness, Contempt, and Crying.

4. Two features with a different mode may combine into a face with a model JE different from the modes of either

[32] Due to the fact that three of the 32 modal JEs comprised only fragments of pictures, these were omitted and only 29 JEs of whole faces and their parts are represented in Table V. These 29 JEs are listed in the same order as in Table I.

TABLE V

AVERAGE PERCENTAGES OF JUDGMENTS ON EYES AND MOUTHS OF THE VARIOUS FACES

Modal Judged Expressions	Descriptive Terms	Laughter	Pleasure	Gloating	Superiority	Disdain	Cynicism	Aversion	Sulkiness	Contempt	Disgust	Sneering	Hate	Anger	Rage	Determination	Horror	Fear	Surprise	Anxiety	Interest	Attention	Reflection	Bewilderment	Doubt
Laughter	W	**58**	24	6											8			2							
	E	26	**31**	1						2	4	6	11	3						2					
	M	34	**41**	1						2			4	5			2	1							
Pleasure	W		**36**	5	12	4	8			3		3							15		4				2
	E		**36**		2		2			3		2				5	3	8	14						
	M	1	20	5	12	2	9	1	5	2	1	13			1						4				
Gloating	W	9		**39**						2	3		5		20									2	
	E									12	6		**31**	**31**	6										
	M	28	72																						
Superiority	W		7	6	**36**	6	5			11	1	2					1		2		4	1			2
	E	2	4	9	14	8	5			5		1					2	3	5			2			3
	M	1	11	8	**16**		2		2	8	8	2	2								4		2	3	4
Disdain	W				31	**48**				11		5													
	E				**41**		10			17															
	M				6				5	16	9												8		3
Cynicism	W			7			**29**			25	21														
	E	3	34				5										3		3		3		5		3
	M		3		6	6	12	5	6	8	**14**	6										3			
Sulkiness	W							9	**17**	9													9		**17**
	E				9													9	**36**						
	M				**13**				**13**	9	9	4	7	7		9									9
Contempt	W			3	8			1		**38**	17	2	4	3		1							2	1	1
	E	6	**15**		6	10	3			1	3	6	4	3		2	6	2	1	1		5			2
	M				5				9	**18**	17	7	2			2							3		2
Disgust	W								1	24	**43**	3	12	1	1	1		2	1			1	1	1	1
	E									6	**15**	**15**	14	3				2	2	1		5	5		
	M								1	**22**	**23**	3				2									
Sneering	W						3	7		22	16	**23**	5	4		11		5							
	E				2	7		5		**19**	7	5	**17**	**19**	4	2							2	2	2
	M							13			13						13								

TABLE V (*Continued*)

Modal Judged Expressions	Descriptive Terms	Disappointment	Sadness	Crying	Pain	Effort	Grief	Appeal	Coyness	Admiration	Amazement	Alarm	Dismay	Distrust	Inferiority	Meanness	Shrinking	Stubborn	Skepticism	Normality	Number of Pictures
Laughter	W				1																6
	E			8			3									1					
	M			1									2								
Pleasure	W							1						2							2
	E	3									7	5	8						2		
	M	1	12				1														
Gloating	W				2																1
	E																				
	M																				
Superiority	W								4					2							6
	E						1		16	1						1					
	M	1	1	2			3														
Disdain	W						3														1
	E							7													
	M	14	27					6	3												
Cynicism	W																				1
	E							37	3												
	M	6	6				3							6	9						
Sulkiness	W															9					1
	E										36										
	M		7															7			
Contempt	W	1	3	1									1	3		1					9
	E						1			2											
	M	5	1	14														3			
Disgust	W	1	1		1									1							5
	E	2				3				1			3					1			
	M	10	6	18														1			
Sneering	W															4					1
	E													4							
	M	20		13	20																

TABLE V (*Continued*)

Modal Judged Expressions	Descriptive Terms	Laughter	Pleasure	Gloating	Superiority	Disdain	Cynicism	Aversion	Sulkiness	Contempt	Disgust	Sneering	Hate	Anger	Rage	Determination	Horror	Fear	Surprise	Anxiety	Interest	Attention	Reflection	Bewilderment	Doubt
Anger	W							2		2	2	1	20	**44**	7	2	2	3	1					3	
	E									6	12	3	10	**20**	13		16								
	M										2		16	16		5	**26**	4							
Rage	W									3	7		17	6	**47**	3	6	5							
	E									8	10	2	**23**	20	11		9	2		1					
	M									4	8		**17**	15	14	5	6	7							
Determination	W									3	2		8	6	2	**56**				1		1	6	2	1
	E				1	1		5					2			**13**		4	5	6	4	7	7	8	7
	M				1	1		1	18	10	5		1		3	**25**								3	1
Horror	W										1				9		**58**	17	3	1					
	E									3	2		9	10	3		**22**	17	12	2				2	
	M									2	7	1	5	9	3		**23**	8	7	1				2	
Fear	W							1			1			7	1		16	**26**	11	5				10	
	E				2									4	2		4	**24**	19	10				6	3
	M									5	5	4	5	2			6	5	**16**				4	9	6
Surprise	W																1	3	**52**	4	2	1		12	2
	E													1				16	**37**	10	4	7		1	2
	M										1	1							**35**	1			1	10	1
Anxiety	W																8	8	11	**26**				23	6
	E																	5	3	**25**				11	6
	M										5	5							**38**	3				11	3
Interest	W		1		1		1							2		1		2	11	1	**34**	11	1	1	9
	E									2									20		17	**21**	9		4
	M		6	4	3	1		1	5	1						2						3	6		1
Reflection	W								5	2	3			5		4			1	1	4	3	**41**	13	4
	E							3	7	9				5		3						12	**14**	7	
	M		3		3				**44**	3						5						6	7		9
Bewilderment	W																	10	10				6	**68**	
	E																	14	**45**	7		24			
	M																			**58**					

TABLE V (*Continued*)

Modal Judged Expressions	Descriptive Terms	Disappointment	Sadness	Crying	Pain	Effort	Grief	Appeal	Coyness	Admiration	Amazement	Alarm	Dismay	Distrust	Inferiority	Meanness	Shrinking	Stubborn	Skepticism	Normality	Number of Pictures
Anger	W			2	2	3															3
	E																				
	M			2	13	7															
Rage	W				2									1							6
	E																				
	M			1	7	4							2								
Determination	W	1												3		2		4			6
	E																				
	M	1	2	5		4												11			
Horror	W				5																7
	E												9				2				
	M			12						1			3				1				
Fear	W	3	4	1			1					2	3	1			2				3
	E																				
	M			8						6											
Surprise	W	1								6	5		8								7
	E	2							1	2	4	2	5								
	M	1	2						6	15	3		5								
Anxiety	W	6	2		3			3													2
	E	13	17	3									8								
	M	5								6			14								
Interest	W								9	2	4		1	3							3
	E		3						2					3							
	M		11	4				1	11											20	
Reflection	W	2					1								2						2
	E					7							5			3					
	M		4						3									11			
Bewilderment	W																				1
	E																				
	M											21									

TABLE V (*Continued*)

Modal Judged Expressions	Descriptive Terms	Laughter	Pleasure	Gloating	Superiority	Disdain	Cynicism	Aversion	Sulkiness	Contempt	Disgust	Sneering	Hate	Anger	Rage	Determination	Horror	Fear	Surprise	Anxiety	Interest	Attention	Reflection	Bewilderment	Doubt
Doubt	W				9					8	1					2			7	2			8	7	34
	E									10	7								10			10			17
	M									16	13	4				13	4			13				2	3
Disappointment	W																						19	9	
	E																	9	6	34			12		
	M								72														6		
Sadness	W			3	6					9	9	2						2		1					1
	E																	20	13	14				11	
	M									19	18	27				2									
Crying	W			1							1		2			3	3	3							
	E	17	16							3	6	9	9	3						4					
	M		2	2				2		11	8	16					17								
Pain	W							2		3	3		3	3	1	5	2	3							
	E	2			1					1	4	6	8	5					1	5	2		2		
	M									10	15		15	9		10		3						1	
Effort	W																								
	E	45		3	8	3	3			10		10			3	3	3		5						
	M												6	11	11	11									
Grief	W				1	1	1	4			2	1	1	1			1	1		3				2	3
	E	2			1		1			1	3		3	3					1	3		1		6	4
	M	2	2	2	1			1	5	8	3					1	1			1		1	2	1	5
Appeal	W				5																	2			
	E	3			10	5	5			3	5	3	3	3							3	3			
	M				6													6	16			10		16	13
Coyness	W		5	11	4											1							2		2
	E		1		3				1	1						4		1			1	24	4		2
	M	9	35				1									18						3	3	3	

TABLE V (*Concluded*)

Modal Judged Expressions	Descriptive Terms	Disappointment	Sadness	Crying	Pain	Effort	Grief	Appeal	Coyness	Admiration	Amazement	Alarm	Dismay	Disgust	Inferiority	Meanness	Shrinking	Stubborn	Skepticism	Normality	Number of Pictures
Doubt	W	5	2		1			3						1				5			5
	E	10								7								4			
	M	4	3	13		3												4			
Disappointment	W	**34**	19											6							1
	E	16											16								
	M																15				
Sadness	W	14	**36**	11	1								6								4
	E	5	17	3									9								
	M	7	7	11																	
Crying	W	1	2	**62**	12	2	9														4
	E		1	14	7		4			2											
	M			**29**	3	2	2						3								
Pain	W	1		7	**47**	5	12														6
	E	1	1	**17**		3	14				1				1						
	M			4	5	2												1			
Effort	W				28	**68**															1
	E					3															
	M				**33**	25															
Grief	W	6	2	11	13	1	**31**	5							1		1				5
	E	5	12	3	11		**20**	6			1			2							
	M	8	10	**25**	3	1	7	3		2						1		1			
Appeal	W		8		7		32	**36**							4						1
	E	5	8		**15**		**15**	10													
	M		6					10													
Coyness	W							12	**50**									1			3
	E							10	23				1	4							
	M			5		4			5									3			

feature. This is found in the case of Gloating, Disdain, Cynicism, Sneering, Interest, Disappointment, Sadness, Pain, Effort, Appeal, and Coyness.

In types 2, 3, and 4 a correspondence is found between the mode of the face and high secondary frequencies of one or both features, which is as follows:

5. The mode of the face corresponds to a high secondary frequency of the two features in the case of Laughter.

6. The mode of the face corresponds to a high secondary frequency of one of the features; of the eyes, in the case of Superiority, Interest, Disappointment, Sadness, Crying, Appeal, and Coyness; of the mouth, in the case of Cynicism, Anger, Rage, and Effort.

7. The mode of the face does not correspond to any high secondary frequency of either feature in the case of Gloating, Disdain, Sneering, Bewilderment, and Pain.

8. However, the modes of the two *features* correspond to a high secondary frequency of the face in the case of Rage; the mode of the eyes, in the case of Disdain, Sneering, Interest, and Appeal; the mode of the mouth, in the case of Cynicism and Effort.

9. Finally, there is no (or very slight) correspondence between the modes or high secondary frequencies of the face and the mode of the eyes in Cynicism, Sulkiness, Contempt, and Effort; of the face and the mode of the mouth in Disdain, Sneering, Anxiety, Interest, Reflection, and Doubt; of the face and the modes of the two features in Gloating, Bewilderment, and Pain.

This analysis indicates that there is no consistent dominance of either eyes or mouth in the determination of the JEs of the faces.[33]

[33] In a very simple experiment, Dunlap fitted the lower part of one picture with the upper part of another, and presented the pairs of composites so obtained along with the two originals from which the parts had been cut. The *O*s were required to characterize the expressions of the two originals, then to determine for each of the two composites which of the two originals it most closely resembled. Dunlap found that the original of the mouth was preferred in the great majority of cases, and concluded that the mouth is more important than the eyes in facial expression. It might be remarked that Dunlap includes under the term "mouth" the lower part of the nose and of the cheeks, the mouth, the chin, and the neck, and it seems obvious enough

These nine types of relations show further that the modal JE of one or both of the features is sometimes lost in the new JE of the face, like (M) Sadness in (W) Disdain, (M) Pain in (W) Sneering, (M) Horror in (W) Anger, (E) Laughter in (W) Crying, etc.; they therefore disprove the statement of Boring and Titchener that "the complication of expressions by mere addition leads to a total expression which is intelligible as a complex of the correlated meanings." The JEs obtained on separate parts of the face cannot be said to be components of the JE of the whole face when no trace of them is found in the latter; *e.g.*, Sadness is not an addition of Fear and Sneering.

Analysis of individual pictures. Although the expression of the whole face is probably never a mere sum of the expressions of the separate features,[34] yet obviously a functional rôle is played by the MIs which can be determined by an analysis of individual photographs and drawings on the basis of the norms given in Table III for the patterns of the various expressions. Different types of integration are evident, in all of which the MIs common to one expression determine the modal JE of the whole face irrespective of whether the separate features, when observed by themselves, had the same, or a different, modal JE.

In one type the MIs common to one expression determine one high modal JE with a low scatter.

Case a. No unrelated MIs are present. Samples of this are Photographs Nos. 3, 4, 5, 6, in which the eyes, the mouth, and the whole face were judged respectively as Surprise, Laughter, Rage, Crying.

that the part of the face that contains larger and more numerous muscles should be more important in facial expression. Differences between judgments of the mouth alone and with the addition of the chin and the neck may be illustrated by two examples from our own series: In Photograph No. 1, the mouth was judged as Rage, Hate, Determination (50%), and as Pain, Effort (37%); the mouth and neck were judged as Horror, Fear (34%), and as Rage (33%), and Pain (17%). In Photograph No. 2, the mouth was judged as Determination (42%), and as Laughter, Pleased (20%); the mouth and neck were judged as Gloating (47%), Superior (27%), Pleased (20%). In the present experiment there is no indication that the mouth presented alone is more important than the eyes.

[34] The few examples under Type 1, p. 137, might be considered as additive.

Case b. The unrelated MIs (which determined the particular modal JEs, or high secondary frequency, of the features) are neutralized in the whole face. Samples follow.

In Photograph No. 7, the MIs common to Laughter have combined at the expense of the expression present in the secondary frequencies of the separate features; thus the eyes were judged as Laughter, Pleasure (70%), and as Hate, Anger (24%); the mouth was judged as Laughter (48%), and as Hate, Anger (40%); the face was judged as Laughter (76%).[35]

Photograph No. 8, owing to an asymmetrical involvement of the eyebrows (the right brow is raised and the left frowning), was tested as follows. Instead of the usual horizontal sections, it was divided *vertically* into two halves by a line passing through the middle of the nose. On the section containing the left eye, 68% of the judgments were given for Anger and Determination, and 25% for Bewilderment, Anxiety, Horror, and Surprise; on the section containing the right eye, 99% of the judgments were given for Fear, Horror, and Surprise. The mouth and eyes were then presented alone (in the usual horizontal sections); the mouth gave 89% Surprise, Horror, Fear, Bewilderment. The eyes gave 59% Fear, Horror, Anxiety, and 19% Anger, Rage. The face gave 84% Fear, Horror, Surprise, Alarm. In the whole face the open mouth has combined with the open eyes and the raised right brow, and the effect of the frowning left brow has become a functional part of the Fear pattern.

In Photograph No. 9, the eyes were judged as Laughter (42%), and as Pain, Crying (35%); the mouth was judged as Contempt, Sneering, Aversion (41%), as Crying, Pain, Effort (34%), and as Pleasure, Gloating (18%); the face was judged as Crying, Pain, Effort (80%). This combination is due to the great similarity of the Laughter and the Crying MIs in the eyes, and of the Contempt and the Pain MIs in the mouth, which become functional parts of the Crying pattern. In this picture the mode of the face resembles the secondary frequencies of both features.

In another type, instead of one set of common MIs being integrated, two or more sets of common elements retain their characteristics in different combinations preferred by different groups of *O*s, thereby dividing the judgments of the face into two or more JEs of high frequency, depending on the relative dominance of the possible patterns for the various *O*s.

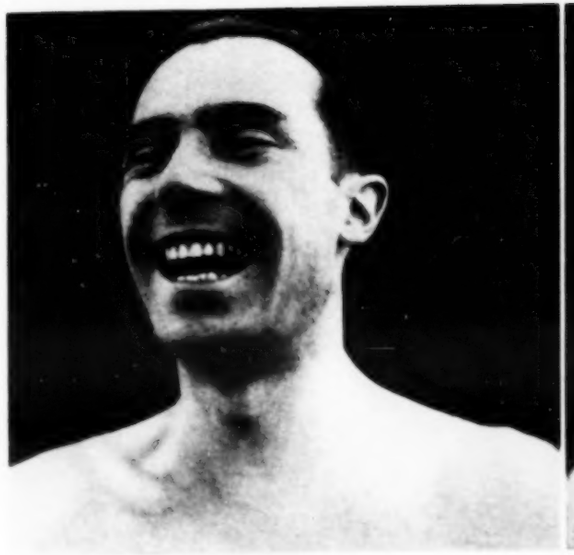
In Photograph No. 10, the eyes were judged as Horror, Surprise, Fear (64%) and as Rage, Anger, Hate (24%); the mouth was judged as Horror, Fear, Surprise (46%), and as Rage, Anger (27%); the face was judged as Horror, Fear, Surprise (65%), and as Rage, Anger, Hate (22%). In this picture the modes and secondary frequencies of the face and of the features are alike. Two interesting facts are that the MIs of the two related expressions, Horror and Rage, have been integrated by one group of *O*s into one expression and by another group into the other expression, and that the backward posture of the head must have been interpreted as a backward or forward motion according to whether the integration took place in the direction of Horror or of Anger.

[35] For convenience in the text, the percentages of JEs closely related in Chart I have been combined.

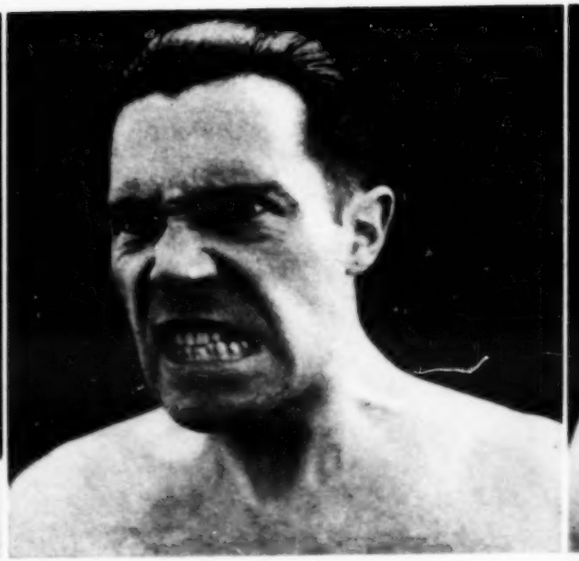
No. 1

No. 2

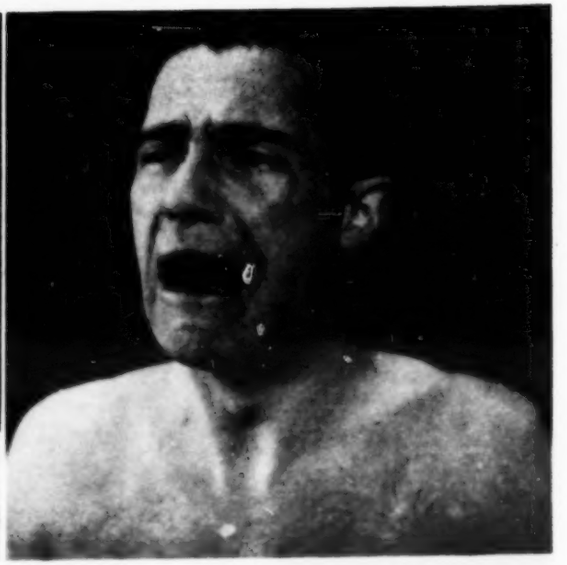
No. 3



No. 4



No. 5



No. 6

In Drawing No. 11, the eyes were judged as Anger, Hate, Rage (68%), and as Contempt, Disgust (18%); the mouth was judged as Crying (50%), and as Horror (34%); the face was judged as Horror (58%), and as Rage (25%). The ascendency of the Horror pattern is here due to its MIs in common with the Rage-pattern and the assimilation of the open mouth of Crying.

In Drawing No. 12, the eyes were judged as Sneering, Disgust, Contempt (68%), and as Hate (25%); the mouth was judged as Hate, Anger (42%), and as Disgust. Contempt (36%); the face was judged as Hate, Anger (30%), as Horror, Fear (30%), and as Pain (27%). In this evenly divided trimodal distribution, only one expression (Hate, Anger) was present in the features. The two others are new resultants which occurred on the basis of numerous MIs shared by Sneering, Anger, and Pain, and by Anger and Horror.

Thus it appears that the participation of most MIs in several expressions enables them, through the expressive possibilities they contain, to be integrated as functional parts of different patterns irrespective of the expressions they underlie in the separate features. The significance of an MI is therefore not constant, but relative to the rest of the pattern, for it is always conditioned by the influence exercised on each MI by all the MIs of the face. The real factor of integration lies in the number and strength of the MIs common to a given expression. One more example will show that from the common MIs of features with different characteristics a common denominator frequently results which characterizes the expression of the whole face. This is shown in Fig. 1 (referring to Photograph No. 9, mentioned on page 146).

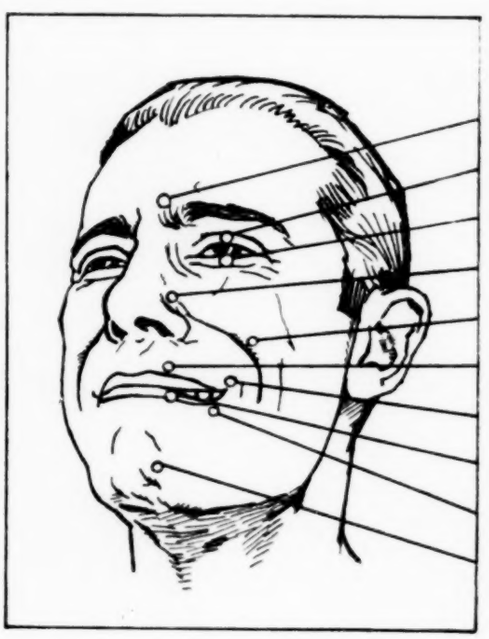
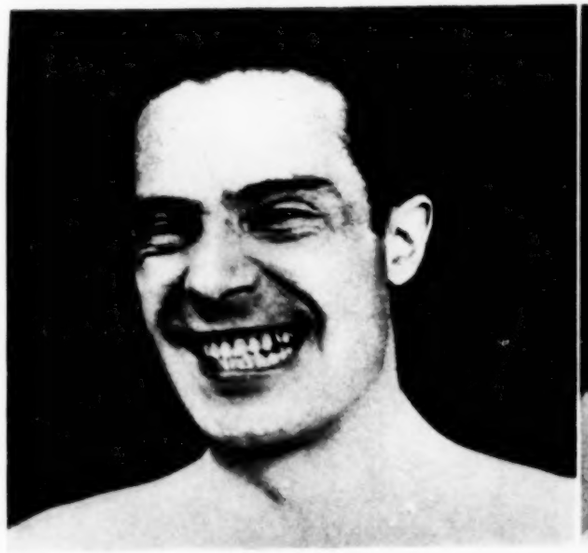
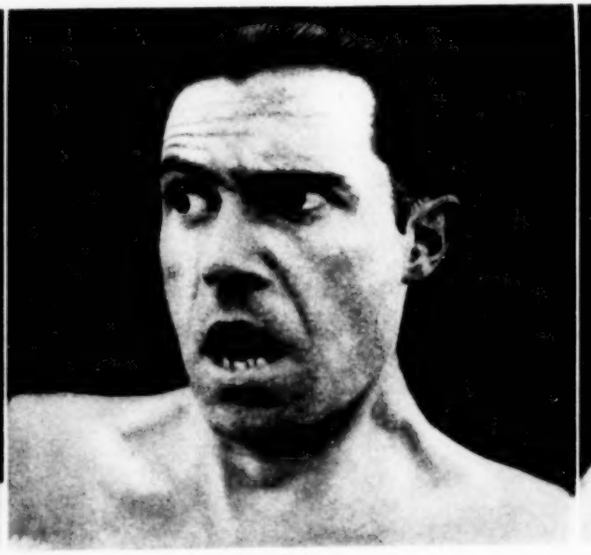


FIG. 1. Illustrating the functional part played by the muscular involvements in the judgment of facial expression.



No. 7



No. 8

No. 9

No. 10

No. 11

No. 12

From this example it can be seen that, while the modal JE of the features has been lost in the new JE of the face, it is only because expressive possibilities for this new JE were contained in the MIs, which gave rise in the features to secondary frequencies almost as high as the modes. The MIs for Crying, being the most numerous in the whole face, dominated the pattern; the eyes and the mouth lost their individual significance for Laughter and Contempt and became functional parts in the Crying pattern. In this example, though the expression of the whole face is thus explainable from a knowledge of the parts and might have been predicted, yet the complete assimilation of the Laughter and Contempt significance of the MIs would not necessarily have been expected. In all the faces examined, the JE of the face was usually to be explained by, but not always predicted from, the above-mentioned factors.

In this section a comparison of the JEs of the separate features with those of the faces, and an examination of the MIs of the various composites concerned, have shown that the stimuli for judgments of expression are the total patterns, in which the individual MIs interact and acquire their final expressive significance from their common expressive possibilities.

Summary

1. The terms used by the 165 observers in judging posed facial expressions of photographs and drawings showed various degrees of agreement. In some cases there was a high modal frequency in the use of one term for a given group of pictures. In other cases the modal frequency was followed by high secondary frequencies. A comparison of the modes with their secondary frequencies afforded a determination of the relationships of the 32 judged expressions occurring as modes, and further, a classification of these relationships into three types: (1) a reciprocal relation between two terms in which each term occurred as a high secondary frequency when the other was the mode; (2) a subordinate relation in which one term occurred as the mode with a high secondary frequency of another without being present as a secondary

frequency for the latter; (3) a bi- or tri-modal relation in which one term is subordinate to two or three other terms.

2. The muscular involvements of the various faces were classified according to the 32 modal 'judged expressions.' While most muscular involvements were present in practically all the expressions, nevertheless there was a unique and distinctive pattern of these muscular involvements for each modal 'judged expression.'

3. There were frequent disagreements between the judgments on the face and its separate features, and also between the judgments on the separate features; but analysis of the individual pictures indicated that those elements that were in agreement combined to characterize the expression of the whole face to which the elements in disagreement became assimilated.

4. The significance of a given muscular involvement is not constant, but is relative to the rest of the pattern.

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FURTHER STUDIES IN OVERLEARNING

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These experiments were conducted to supply additional information upon the following questions. As the degree of learning (or the amount of practice) is varied, will the degree of retention vary proportionally? and Will the relation between the degree of learning and the degree of retention vary with the interval between learning and recall?

A previous study [1] indicated that a certain degree of overlearning, up to 50%, was highly economical from the standpoint of retention for intervals of 2 to 28 days, and that the larger the interval the greater was the economy. Further increases of overlearning, however, proved to be uneconomical for most intervals. These results did not agree with Luh's.[2] In his experiments and in mine the subjects memorized such ideational material as lists of nouns and nonsense syllables. In the present experiments the subjects acquired an act of skill, mastering a kinæsthetic (or finger) maze.

PART I

After preliminary experimentation, eight mazes of apparently equal difficulty were selected. Instead of tracing the pathway with a stencil, as is done with a stylus maze, S traced the maze with one finger, the path consisting of small strips of wood nailed on a board one foot square. S was cautioned to use one finger only, the rest of the hand was to furnish no other points of contact for information. S was seated at the table; instead of a blindfold, a white paste-board was placed horizontally before him, about nine inches above the maze. This did not hamper S; but it efficiently prevented him from

[1] Wm. C. F. Krueger, The effect of overlearning on retention, this JOURNAL, 1929, 12, 71–78.

[2] C. W. Luh, The conditions of retention, *Psychol. Monog.*, 1923, 31 (no. 142), 44.

seeing the maze or the movements of his hand. Only one new maze was mastered on any day.

The three degrees of learning used were 100% learning, 50% overlearning, and 100% overlearning. By 100% learning we meant the degree of attainment at which S was first able to trace the correct path without an error. The procedure gave the scores for (1) the number of trials necessary to learn, (2) the total time (sec) required, and (3) the total number of errors made. To obtain 50% overlearning the trials were continued until the number was increased by one-half of the number of trials required for the 100% degree. If 6 trials were needed, *e.g.*, to trace a maze without error, 3 more were added; if 8 trials were necessary, 4 more were given, *etc.* For the odd-numbered trials, as 3, 5, 7, *etc.*, one-half of the next higher number was added, *e.g.*, one-half of four, six, eight, and so on. In a similar manner, 100% overlearning meant that S was given twice the number of trials required for tracing without error. The range of intervals was 1, 2, 3, 4, 7, and 14 days. After the specified interval, the Ss were required to relearn the maze to the 100% degree. This relearning then gave three scores, (1) number of trials necessary for relearning, (2) the time required for, and (3) the number of errors made during the relearning.

Six groups, 32 college students in each group, were used for the various intervals. The groups seemed to be well equated. One group of 32 Ss was used for each of the three degrees of learning for each interval of time. The same eight mazes were used for each condition of learning. Two methods were used to eliminate the possibility that the differences between the learning and the relearning scores might be due to practice. First, all Ss had to master at least four mazes before being used in this study, and, secondly, one-half of the Ss took the order 100%, 150%, and 200% learning, while the other half took the reverse order. To avoid the possibility that the differences in retention scores might be due to differences in the difficulty of the mazes, each S learned a different maze for each given degree of learning.

Retention was measured in three ways. (1) The use of the usual formula for the 'saving method' gave one set of retention-scores. (2) Subtracting the time required for relearning the maze from the time necessary for learning the maze to the 100%-degree stage gave another set of scores. The time consumed during the overlearning was never in-

cluded in the minuend. Thus the differences in relearning time for the three degrees of learning were thought of as indicators of the effect of additional learning or practice. (3) Subtracting the number of errors made during relearning from the number of errors made during learning the maze to the 100% degree of mastery gave the third set of scores. No errors made during the overlearning period were included in the minuend. All retention-scores quoted in Tables II, III, and IV are based upon the average of 32 scores, one score from each subject of the group; four scores were obtained from each of the eight mazes.

In Table I is found, for each of the eighteen conditions, the average number of trials necessary (1) to learn and (2) to relearn a maze. The third column shows the average number of trials necessary to master a maze to the specified

TABLE I

AVERAGE NUMBER OF TRIALS TO LEARN AND TO RELEARN A MAZE

Intervals (days)	Degree of Learning	Trials Required to Learn a Maze (av)	Trials for 100% Learning (av)	SD for 100% Learning Score	PE for 100% Learning Score	Trials to Relearn a Maze 100% (av)	SD for Relearning Score	PE for Relearning Score
1	100	4.19	4.19	1.40	.17	2.38	.89	.11
1	150	7.37	4.72	1.60	.19	2.06	.82	.10
1	200	9.68	4.84	1.64	.20	1.99	.99	.09
2	100	4.66	4.66	1.32	.16	3.25	1.48	.18
2	150	7.19	4.59	1.27	.15	2.69	1.24	.15
2	200	9.32	4.66	1.11	.13	1.91	.74	.09
3	100	4.60	4.60	1.27	.15	3.31	1.18	.14
3	150	7.03	4.53	1.30	.15	2.44	.81	.10
3	200	9.18	4.59	1.41	.17	2.00	1.13	.13
4	100	4.69	4.69	1.38	.16	3.59	1.30	.15
4	150	7.19	4.60	1.30	.15	2.78	1.05	.12
4	200	9.20	4.60	1.63	.19	2.31	1.21	.14
7	100	4.03	4.03	1.21	.14	2.81	.81	.10
7	150	6.91	4.41	1.43	.17	2.88	1.70	.20
7	200	9.44	4.72	1.51	.18	2.22	1.08	.13
14	100	4.10	4.10	1.60	.19	2.88	.80	.10
14	150	6.23	4.03	1.58	.19	2.69	.85	.10
14	200	9.06	4.53	1.25	.15	2.72	1.15	.14

degree of learning. The fourth column states the average number of trials to attain the 100% learning. The seventh column gives the average number of trials necessary to relearn a maze. The other columns contain the respective measures of variability, the S.D.'s and P.E.'s for each average.

One may readily see that the learning-scores, based upon 100% learning, were approximately the same for all eighteen conditions. Therefore any differences in retention-scores cannot be accounted for by differences in the learning-scores, or due to differences in the difficulty of the mazes.

TABLE II

AVERAGE PERCENTAGE RETAINED AS MEASURED BY THE SAVING METHOD

Intervals (days)	Degree of Learning (%)	Retained as Meas'd by Sav. Method (% av)	SD for Retention Score	PE for Retention Score	Reliability of Difference between Means for 100% and 150% Learning	Reliability of Difference between Means for 150% and 200% Learning
1	100	36.56	33.90	4.00	2.82	
1	150	51.40	28.50	3.39		3.57
1	200	67.81	26.10	3.11		
2	100	32.34	25.35	3.02	2.84	
2	150	45.25	28.50	3.39		3.18
2	200	63.99	40.50	4.82		
3	100	29.93	22.20	2.64	3.75	
3	150	44.31	23.25	2.77		3.37
3	200	60.09	31.65	3.77		
4	100	26.87	21.45	2.55	3.39	
4	150	39.91	24.15	2.87		4.26
4	200	58.85	28.50	3.39		
7	100	24.06	19.60	2.33	2.56	
7	150	33.84	25.50	3.03		4.18
7	200	51.97	26.10	3.11		
14	100	22.47	20.85	2.48	2.58	
14	150	31.34	20.10	2.39		3.37
14	200	44.81	26.20	3.12		

The average retention-scores are listed in Tables II, III, and IV. In Table II are given the average retention-scores for all conditions as derived by the 'saving method.' The last two columns of Table II state the ratio of the difference between the respective means to the P.E.(diff.).

Table III contains the average absolute difference between the time required for learning and the time necessary for relearning a maze to the 100% degree. The time needed for the overlearning is not included in these scores.

TABLE III

RETENTION AS MEASURED BY THE AVERAGE DIFFERENCE BETWEEN ERRORS MADE WHILE LEARNING AND RELEARNING A MAZE

Interval (days)	Degree of Learning (%)	Retention as Meas'd by Number of Errors Made for 100% Learning (av)	SD for Retention Score	PE for Retention Score	Reliability of Difference between Means for 100% and 150% Learning	Reliability of Difference between Means for 150% and 200% Learning
1	100	15.03	11.30	1.34	3.54	
1	150	21.19	9.35	1.11		2.27
1	200	25.19	11.50	1.37		
2	100	13.91	10.75	1.28	3.06	
2	150	19.44	10.60	1.26		2.11
2	200	23.38	11.70	1.38		
3	100	10.00	7.50	.89	2.16	
3	150	13.00	9.00	1.07		2.87
3	200	17.59	10.00	1.19		
4	100	7.65	6.50	.77	1.87	
4	150	9.71	6.75	.80		3.21
4	200	13.47	7.20	.86		
7	100	6.54	4.75	.57	1.83	
7	150	8.37	7.05	.84		2.56
7	200	11.72	8.40	1.00		
14	100	6.18	5.60	.67	1.00	
14	150	7.12	5.60	.67		2.50
14	200	9.72	6.70	.80		

Table IV states the average absolute difference in errors made during learning and relearning a maze to the 100% degree. No errors made during overlearning are included in these scores.

Tables II, III, and IV indicate that, for every interval, the highest retention-scores were obtained with 100% overlearning, while the lowest retention-scores always occurred with the 100% learning. The consistency of the relative difference between two respective means is usually supported by statistical validity, especially in regard to retention-scores

derived by the saving method. The difference between the mean retention-score for the 100% degree of learning and 150% degree of learning is, with two exceptions, always less than the difference between the average retention-scores for 150% and 200% learning. This holds true for all methods of measuring retention, and for all intervals.

TABLE IV

RETENTION AS MEASURED BY THE AVERAGE DIFFERENCE BETWEEN TIME REQUIRED TO LEARN AND TO RELEARN A MAZE (IN SEC)

Interval (days)	Degree of Learning (%)	Retention as Meas'd by Difference in Learning and Relearning Time (av sec)	SD for Retention Score	PE for Retention Score	Reliabi ity of Difference between Means for 100% and 150% Learning	Reliabi ity of Difference between Means for 150% and 200% Learning
1	100	72.69	67.80	8.07	1.32	
1	150	86.62	57.00	6.78		3.69
1	200	124.40	64.50	7.68		
2	100	56.62	46.20	5.50	2.79	
2	150	79.53	51.90	6.08		4.18
2	200	120.34	64.20	7.64		
3	100	54.28	41.10	4.49	2.01	
3	150	71.97	63.60	7.59		2.47
3	200	100.84	75.00	8.92		
4	100	46.72	44.40	5.28	1.53	
4	150	57.56	39.60	4.71		4.33
4	200	92.41	54.90	6.53		
7	100	38.25	33.60	4.00	1.81	
7	150	49.44	39.60	4.71		3.45
7	200	76.46	52.50	6.25		
14	100	37.34	28.22	3.38	1.22	
14	150	44.40	39.30	4.68		2.59
14	200	63.18	46.50	5.53		

In order to determine whether the relation between the degree of learning and the degree of retention varies with the interval between learning and recall, we computed, as in our previous study, the ratios between the retention-scores for 100% and 150% learning, and the ratios of retention-scores for 150% and 200% learning. The respective degrees of learning stand in the ratios of 1 : 1.5, and 1 : 1.33. The corresponding ratios of retention are obtained by dividing

the retention-scores for each interval by the retention-scores for the lesser degree of learning. For example, according to Table II, the retention-scores for the 100% and 150% learning for the two-day interval are in the ratio of 32.34 : 45.25, and the retention-scores for the 150% and 200% learning are in the ratio of 45.25 : 63.99. By dividing the first ratio by 32.34 and the second ratio by 45.25 (the retention-scores for the lesser degree of learning) we got the simplified ratios of 1.00 : 1.34 and 1.00 : 1.41. These ratios mean that an increase of learning from 100% to 150% yielded a corresponding increase in retention of 34%, while increasing learning (or practice) by an additional 33.3% (from 150% to 200%) increased retention by 41%. Tables V and VI contain the series of ratios based upon retention-scores derived by the 'saving method.'

TABLE V

RATIO OF DEGREE-OF-LEARNING AND CORRESPONDING RATIOS-OF-RETENTION FOR 100% AND 150% LEARNING

Ratio of Learning	Ratios of Retention as Measured by the Saving Method					
	Intervals (days)					
	1	2	3	4	7	14
1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.50	1.40	1.34	1.48	1.48	1.41	1.39

TABLE VI

RATIO OF DEGREE-OF-LEARNING AND CORRESPONDING RATIOS-OF-RETENTION FOR 150% AND 200% LEARNING

Ratio of Learning	Ratios of Retention as Measured by the Saving Method					
	Intervals (days)					
	1	2	3	4	7	14
1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.33	1.32	1.41	1.35	1.47	1.54	1.43

Applying the same procedure to retention-scores in Tables III and IV, we obtained the series of ratios of retention-scores presented in Tables VII, VIII, IX, and X.

TABLE VII

RATIO OF DEGREE-OF-LEARNING AND CORRESPONDING RATIOS-OF-RETENTION FOR 100% AND 150% LEARNING

Ratio of Learning	Ratios of Retention as Measured by Differences between Number of Errors Made during Learning and Relearning					
	Intervals (days)					
	1	2	3	4	7	14
1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.50	1.41	1.39	1.30	1.27	1.28	1.15

TABLE VIII

RATIO OF DEGREE-OF-LEARNING AND CORRESPONDING RATIOS-OF-RETENTION FOR 150% AND 200% LEARNING

Ratio of Learning	Ratios of Retention as Measured by Differences between Number of Errors Made during Learning and Relearning Intervals (days)					
	1	2	3	4	7	14
1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.33	1.19	1.20	1.43	1.39	1.40	1.36

TABLE IX

RATIO OF DEGREE-OF-LEARNING AND CORRESPONDING RATIOS-OF-RETENTION FOR 100% AND 150% LEARNING

Ratio of Learning	Ratios of Retention as Measured by Differences between Learning and Relearning Time Intervals (days)					
	1	2	3	4	7	14
1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.50	1.19	1.40	1.33	1.22	1.29	1.16

TABLE X

RATIO OF DEGREE-OF-LEARNING AND CORRESPONDING RATIOS-OF-RETENTION FOR 150% AND 200% LEARNING

Ratio of Learning	Ratios of Retention as Measured by Differences between Learning and Relearning Time Intervals (days)					
	1	2	3	4	7	14
1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.33	1.44	1.51	1.40	1.61	1.55	1.42

CONCLUSIONS

1. As the degree of learning was increased from 100% to 150%, there was always an increase in all retention-scores for all intervals, and this proportional increase was always less than 50%. There was no consistent proportional increase or decrease of retention as the interval was varied.

2. As the degree of learning was increased from 150% to 200% (or by an additional third), the corresponding increase in retention-scores usually was more than a third, especially for the longer intervals. But no consistent relationship between the proportional increase in retention and the length of the interval was found.

The results substantiated our previous discovery that overlearning, when within the range of our experiment, is not

detrimental but economical. In fact, the increase from the 150% degree of learning to the 200% degree was proportionally more economical than the increase from the 100% degree to the 150% degree.

PART II

The results of the foregoing experiment suggested that the study be extended to note the effect of a still higher degree of learning, namely 200% overlearning. Two groups, A and B, each with 32 Ss of the same type as in Part I, were used. Every S had the preliminary training of mastering at least four mazes.

The eight mazes (the same as used before) were mastered and the trials continued until there was 200% overlearning; *i.e.*, each subject continued to trace the maze until he had three times the number of trials necessary to learn the maze to the 100% degree (without error). Each S of one-half of Group A mastered a different maze to the stated degree of overlearning and relearned the maze after a two-day interval; then a different maze was mastered, to be relearned after a three-day interval. A third maze was learned and relearned after a four-day interval. The other half of Group A learned the mazes in the reverse order, namely, four-, three-, and two-day intervals. One-half of Group B learned the mazes with the intervals of 1, 7, and 14 days, while the other half

TABLE XI

AVERAGE NUMBER OF TRIALS TO LEARN AND RELEARN A MAZE

Interval (days)	Degree of Learning (%)	Trials Req'd to Learn a Maze (av)	Trials for 100% Learning (av)	SD for Learning Score	PE for Learning Score	Trials to Relearn a Maze 100% (av)	SD for Relearning Score	PE for Relearning Score
1	300	13.89	4.63	1.60	.19	1.72	.76	.09
2	300	13.98	4.66	1.69	.20	1.50	.66	.08
3	300	13.89	4.63	1.60	.19	1.72	.76	.09
4	300	13.14	4.38	1.22	.15	1.78	.65	.08
7	300	12.39	4.13	1.33	.16	1.97	1.06	.13
14	300	12.18	4.06	1.21	.14	2.35	1.08	.13

of Group B took the order of 14-, 7-, and 1-day intervals. The results, tabulated and calculated by the same procedure as in Part I, are given in Tables XI to XIV.

TABLE XII

AVERAGE PERCENTAGE RETAINED AS MEASURED BY THE SAVING METHOD

Interval (days)	Degree of Learning (%)	Retained as Meas'd by Sav. Method (av %)	SD for Retention Score	PE for Retention Score	Reliab'y of Diff. bet. Means for 200% and 300% Learning
1	300	72.86	27.00	3.21	1.08
2	300	78.31	26.85	3.20	2.47
3	300	67.75	28.50	3.39	1.51
4	300	63.94	17.70	2.11	1.28
7	300	59.28	34.20	4.07	1.43
14	300	52.10	39.15	4.66	1.48

TABLE XIII

RETENTION AS MEASURED BY THE AVERAGE DIFFERENCE BETWEEN ERRORS MADE WHILE LEARNING AND RELEARNING A MAZE

Interval (days)	Degree of Learning (%)	Retention as Meas'd by Errors in Learning and Relearning (av)	SD for Retention Score	PE for Retention Score	Reliab'y of Diff. bet. Means for 200% and 300% Learning
1	300	26.25	11.40	1.36	.55
2	300	23.56	10.70	1.27	.10
3	300	21.03	13.55	1.61	1.72
4	300	17.99	6.75	.80	3.87
7	300	13.16	8.95	1.07	1.00
14	300	11.35	6.60	.79	1.46

Since the subjects, materials, and conditions of learning in Part II were so similar to those in Part I, the results seemed comparable. In order to discover the relative effect of 200% overlearning we compared the retention-scores with those for 100% overlearning of Part I.

The average retention-scores for 200% overlearning for each respective interval were always higher than the corre-

sponding retention-score for 100% overlearning. These differences, however, did not always have a high statistical validity, although the relation was consistent.

TABLE XIV

RETENTION AS MEASURED BY THE AVERAGE DIFFERENCE BETWEEN TIME REQUIRED TO LEARN AND RELEARN A MAZE (SEC)

Interval (days)	Degree of Learning (%)	Retention as Meas'd by Diff. in Time for Learning and Re-learning (av)	SD for Retention Score	PE for Retention Score	Reliab'y of Diff. bet. Means for 200% and 300% Learning
1	300	128.80	60.12	7.15	.45
2	300	140.06	76.80	9.14	1.66
3	300	130.81	81.60	9.71	2.27
4	300	116.50	71.40	8.50	2.25
7	300	86.72	60.45	7.19	1.08
14	300	81.06	48.00	5.71	2.25

Ratios of average retention-scores for 200% overlearning to the retention-scores for 100% overlearning are shown in Tables XV to XVII.

TABLE XV

RATIO OF DEGREE-OF-LEARNING AND CORRESPONDING RATIOS-OF-RETENTION FOR 200% AND 300% LEARNING

Ratio of Learning	Ratios of Retention as Measured by the Saving Method					
	Intervals (days)					
	1	2	3	4	7	14
1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.50	1.08	1.22	1.13	1.09	1.14	1.16

TABLE XVI

RATIO OF DEGREE-OF-LEARNING AND CORRESPONDING RATIOS-OF-RETENTION FOR 200% AND 300% LEARNING

Ratio of Learning	Ratios of Retention as Measured by Differences between Number of Errors Made during Learning and Relearning					
	Intervals (days)					
	1	2	3	4	7	14
1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.50	1.04	1.01	1.20	1.33	1.12	1.17

TABLE XVII

RATIO OF DEGREE-OF-LEARNING AND CORRESPONDING RATIOS-OF-RETENTION FOR 200% AND 300% LEARNING

Ratio of Learning	Ratios of Retention as Measured by Differences between Learning and Relearning Time Intervals (days)					
	1	2	3	4	7	14
1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.50	1.04	1.16	1.30	1.26	1.14	1.28

CONCLUSIONS

1. The higher degree of overlearning always has the higher average retention-scores for each interval.

2. The respective increase in retention-score is not very large, although consistent.

3. The increase from 100% overlearning to 200% overlearning is not as economical as 50% and 100% overlearning.

4. There is no consistent variation between increase in retention and length of interval.

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THE RETENTION AND RECOGNITION OF PATTERNS IN MAZE LEARNING

BY THURMAN C. SCOTT

Ohio University[1]

The object of this investigation was to determine how well maze patterns are retained by human subjects, to what extent they are recognized when repeated, and to what degree they function even though they are not recognized. Two other problems which are intimately related to the above have been discussed to a certain extent. They are, first, the kinds of imagery involved, the relative value of each, and the changes in the kind of imagery from one type of maze to another or from day to day on the same type of maze, and, secondly, the importance of practice effect in comparison with that of the retention of pattern, and the interference of pattern when three mazes are learned. This study grew out of, and elaborates, an investigation of the relative ease with which a maze is learned with the right or left hand, the mirror-reversal of which has been learned the previous day with the right hand.

History of the problem. The problem of the recognition of maze patterns seems to have been given but little attention. Heron[2] makes a slight reference to recognition. His subjects learned five mazes, one at a sitting with an interval of a week between sittings, and then repeated the first, second, and fourth mazes, upon the first, second, and third weeks following. He does not give the number of recognitions, merely stating that few of the subjects recognized the mazes.

The retention of maze patterns has been a subject of somewhat more general interest, several studies having been made. In only one of these studies, however, was retention the main and only point of the experiment. This clean-cut study was made by Tsai,[3] who had six groups of 16 subjects each. After learning a maze, the groups were tested for retention after intervals of 1–9 weeks. The subjects were told on the date of testing that they were being given the same maze. Tsai found that

[1] This study was carried out in the Psychological Laboratory of Princeton University.

[2] W. T. Heron, Individual differences in ability versus chance in learning the stylus maze, *Comp. Psychol. Monog.*, 1924, 2, 10.

[3] C. A. Tsai, A comparative study of retention curves for motor habits, *ibid.*, 1924, 2, 1–29.

the percentage of errors saved varied from 94 percent after an interval of one week to 80 percent after an interval of nine weeks. He also tested rats for maze-habit retention and found that they retained the habit more effectively than human subjects up through a period of five weeks. Human subjects, however, were superior for longer periods than this. Retention was the main point of Brockbank's [4] study. He trained albino rats on Watson's circular maze and tested for retention different groups at intervals of 30, 45 and 70 days. He found a great saving, but was more interested in seeing what effect the distribution of trials in learning had upon retention, and in seeing whether or not the dominant errors in learning proved to be the dominant errors in relearning. He also gives a review of previous studies on the retention of motor acts by animals. Webb [5] repeated mazes in the second half of his experiment (where he was studying retroaction); but his results have very little bearing on the present study, since the conditions of his experiment were unlike ours. He used an interval of 30 days between learning and repetition, the test-group requiring this amount of time to learn another maze. The instructions to the subjects were also quite different, and were very meagre, it being left for them to find out for themselves when they were given a new maze. Webb got some slight evidence for retroaction; but this might have been due to the fact that the subjects probably had a mental set for the same maze and were somewhat disturbed when they found the maze different. He used too few subjects in this part of his study; one group of 6 subjects and the rest of 5 each, with wide individual differences. Webb also repeated mazes on rats under the above conditions and obtained about the same results, but again used too few subjects. Heron's [6] subjects relearned mazes; but he does not state the amount of saving, being primarily interested in the correlation between the learning and the relearning. Wiltbank [7] repeated mazes on rats after four intervening mazes had been learned, and found that there was very little saving. He found quite a saving, however, when two successive, four-section mazes had one identical section. The saving was about the same when the third section was repeated as when the first was repeated. He concluded, however, that the more expeditious learning of the second maze was not due to the saving of errors in the identical part. Koch [8] repeated mazes 48 hours after they were learned, but obtained no data bearing on this problem, since he was primarily interested in the effects of varying amounts of mechanical guidance. It is not clear, either, whether or not the subjects knew that they were being given the same maze. Perrin [9] gave his subjects mirror reversals of mazes they had already learned and found that they had very little trouble running them. He also gave them the same mazes turned through an angle of 180 , so that the subjects started at the position of the former exits. He found that these patterns were equally easy. His subjects, however, were informed in both cases as to the nature of the change.

[4] T. W. Brockbank, Redintegration in the albino rat; a study in retention, *Behav. Monog.*, 1919, 4, 1–66.

[5] L. W. Webb, Transfer of training and retroaction; a comparative study, *Psychol. Monog.*, 1917, 24, (no. 104), 1–90.

[6] Heron, *op. cit.*

[7] R. T. Wiltbank, Transfer of training in white rats upon various series of mazes, *Behav. Monog.*, 1919, 4, 1–65.

[8] H. L. Koch, The influence of mechanical guidance upon maze learning, *Psychol. Monog.*, 1923, 32, (no. 147), 1–113.

[9] F. A. C. Perrin, An experimental and introspective study of the human learning process in the maze, *Psychol. Monog.*, 1914, 16, (no. 70), 1–97.

Hunter[10] also rotated a simple right-left alternating maze through 180° so that all the moves were the opposite of what they had been, and found that most of the subjects mastered it very readily. This maze, however, was too easy for the test to be of much value. It is not quite clear either, whether or not his subjects were informed of the change, but it is assumed that they were not.

These are the main studies which are more or less pertinent to the main part of this investigation. Other studies will be mentioned later in connection with the particular phase of the problem on which they have bearing.

Experimental Procedure

Apparatus. The mazes varied from identity to as great a degree of dissimilarity as possible for the kind used. Most of them were Warden's[11] 'T' type, as used by him in his study of primacy and recency as factors in cul-de-sac elimination.

They are the same size as Warden's, the horizontal runs being 4 in. long, the vertical runs 1 in. long, the groove ¼-in. wide, and the circular entrance and goal ¾-in. in diameter. Two of the mazes, *C* and *D*, as shown on page 167, are his patterns 1 and 2, having ten culs-de-sac each, and all the other main mazes (except three, *N*, *W* and *E*) differ only in sequence of turns. Two of these three, *N* and *W*, are the same as Warden's, except that the cross of the *T* is V-shaped rather than straight in the center, becoming horizontal toward the end of the cross. The side of the V makes an angle of 55° with the vertical, so that each unit of the true path as well as each cul-de-sac has angles of 55°, 35° and 90° instead of two angles of 90° each. The units of these mazes are the same length in the horizontal direction as Warden's. They extend two inches on either side of the stem of the *T*, these two inches being divided equally between the oblique and the horizontal lines. The vertical lines are only ⅞-in. in length; but, because of the oblique lines, the total length of each of these two mazes is 14 in., whereas Warden's type of maze is only 11 in. in length. The other maze, *E*, is of the usual "T" type without hooks on the end. The vertical lines are 3⅞ in. long, and horizontal 3⅛. The vertical blinds are 1⅛ in. long, the horizontal ⅞ and both are straight. The width of the groove and the diameter of the circles are the same as in the other mazes. The total length of this maze is 9¼ in. and the total width is 12 in. It has 18 culs-de-sac, and the pattern is circuitous. The two preliminary mazes are the same type as Warden's except that they are just half the size, having only five culs-de-sac.

All these mazes were cut out of a double thickness of heavy cardboard, and the groove was ⅛-in. in depth. Another thickness was used as a bottom for this outline, and these three thicknesses were mounted on wooden boards by means of thumb tacks. The pieces of cardboard for *N* and *W* were 14 x 17¼ in., the rest being 14 x 14½. The cardboards for the preliminary mazes were of like width, but somewhat shorter. In every maze the cardboard was cut out from underneath the circle at the goal, making a slight drop-off which served as a signal for the goal.

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[10] W. S. Hunter, Habit interference in the white rat and in human subjects, *J. Comp. Psychol.*, 1922, 2, 25–59.

[11] C. J. Warden, Primacy and recency as factors in cul-de-sac elimination in a stylus maze, this Journal, 1924, 7, 98–116.

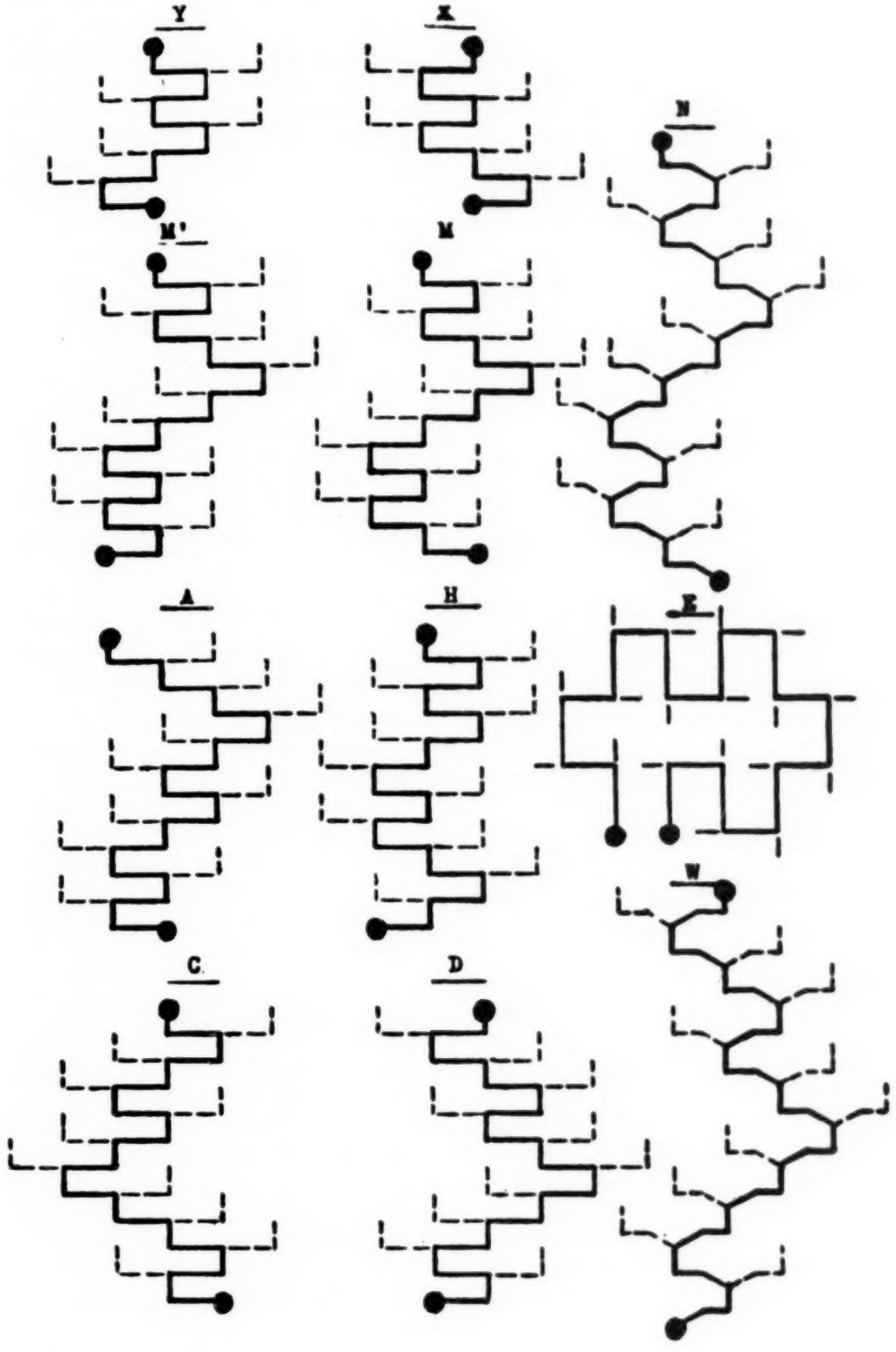

FIG. 1.

These mazes were held in place on top of a table of standard height by nails driven in the table top so as to form an outline for the boards. Covering these mazes was a frame 8 in. high on one side and 10½ in. on the other. This frame was 30 in. wide and 16 deep, and was covered by a piece of heavy blue denim, the free end of which was attached around the subject's neck as an apron. This adequately hid the maze from the subject, and was no hindrance to him. The higher end of the frame, next to the experimenter, was open and enabled the experimenter to observe S's movements and to record his errors.

The stylus used in this experiment was made out of a 2¾-in. film-roll. One of the metal ends was taken off, the other serving as a flange, and a piece of a tenpenny nail was inserted in the flange end of the roll. This nail projected ⅞-in. and was filed so as to give a smooth, blunt end. It was slightly over ⅛-in. thick and thus ran easily in the ¼-in. groove.

Subjects. A total of 230 subjects were used in this experiment. One hundred and sixty were undergraduates taken about equally from the three upper classes. About half of them were majoring in Psychology. There were 46 graduate students, two of whom were in Psychology; 16 instructors, five of whom were in Psychology; and 8 women, secretaries and wives of graduate students and instructors. These different classes of subjects were scattered fairly evenly throughout the groups. Three Ss learned two groups of mazes each, so in actuality there were only 227 persons.

Method of procedure. Every possible attempt was made to prevent the subjects from feeling ill at ease. It was explained that learning a maze was not a test of one's intelligence, and it was pointed out that it was highly desirable for the subjects to take a 'problem attitude' rather than a 'self attitude.' They were told that they were to learn one maze a day, starting with a very simple one. At this point they were asked to read the following instructions:

1. The subject is to strive for an early mastery of the maze, that is, to learn the true path from the entrance to the goal as quickly as possible. Accuracy, however, should not be sacrificed for speed.
2. The maze will be considered learned when the subject has made five[12] runs in succession without error.
3. An error is defined as a turn from the true path into a blind alley.
4. Time will be counted from the starting signal until the exit is reached.
5. Fifteen or twenty trials a day will be given until the maze is learned.
6. An interval of one and one-half minutes will be given between trials.
7. Subjects are not to discuss the mazes with one another.

[12] In several cases Ss made errors after four perfect runs. These errors seemed to be due to the fact that they knew they had made four perfect runs and were trying too hard on the fifth trial. For this reason the maze was considered learned when four successive perfect runs were made even though five were required.

When the Ss had read these instructions, they were shown maze *Y* and were told that all the mazes they would have would be similar to it in the following respects. All were cut out of cardboard, all had the same circular entrance, and the same circular exit with the drop-off which served as a signal for the goal, and all had alleys of the same width. It was also added that if there were other similarities, or, if there were dissimilarities, the subjects would have to find them as the maze was learned. This statement was repeated each day. The Ss were then seated at the table, and after being cautioned against gripping the stylus too tight, and after being allowed to feel around the edge of the cardboard so as to get some idea of the size of the maze, they learned maze *X* the first day. They were allowed to feel around the mazes each day, but no instructions were given after the first day except for the repetition of the statement mentioned above in regard to similar features. Immediately after each maze was learned the Ss were asked to make two drawings of the true path, the first without and the second with vision. They were asked to make these drawings as near the actual size of the maze as possible.

The 1½-min interval between trials was used for recording time and errors and for comments from the Ss, who were encouraged to talk informally and as much as possible. When the experimenter was still in doubt as to the kinds of imagery used when S had finished a maze, he questioned S on this point.

All the groups except Group 9 were shown *Y* and learned *X* the first day, and were told that this was preliminary to the main part of the experiment which began the second day. They learned the other mazes one-a-day on successive days. Group 9 learned a large maze the first day without any preliminary training, the object being to find out how much the other groups were profiting by the first day's experience.

Method of recording. An error, as stated above, was defined as a turn from the true pathway into a blind alley. An arbitrary decision was made, however, not to count such a movement as an error unless it reached the half-way mark

on the 2-in. horizontal run-way. Retracing was not counted as an error unless S went into a blind alley. These errors were recorded as made, and could easily be summed up at the end of each trial. Points at which hesitation or wavering occurred were also noted. Time for each trial was taken with a stop watch. The complete record then for each subject included the total number of trials required to learn the maze,[13] the number of errors made on each trial, the alleys in which they were made, the total number of errors made and the time required on each trial, and the total time required on all trials.

Results

The quantitative results of this experiment are reported in terms of the total number of trials required to learn the maze and the total number of errors made in the course of learning. Emphasis is laid on errors. It seems to be the consensus of opinion among previous investigators that errors are a better individual measure of maze-learning than trials. Trials, as pointed out by Tolman and Nyswander,[14] are a less valid measure since the amount of material learned on one trial differs from that learned on another. Trials, therefore, cannot be considered as units. Time scores are not included in this report, since time is considered to be the least satisfactory of the three measures. Time is least satisfactory for two reasons. First, as pointed out by Tolman and Nyswander,[15] individuals vary greatly in the factor of what they call pure speediness *per se*, that is, the normal speed for one individual is far slower than that for another. This is as true of human subjects as of animals. Secondly, our Ss varied in their interpretation of the instructions as to speed and accuracy, some emphasizing speed more than others. In addition to this, some Ss, even though they realized that accuracy was more important, seemed more aware of the time-element than others.

[13] The first perfect trial of the series of five was included in the total number of trials required to learn the maze.

[14] E. C. Tolman & D. B. Nyswander, Reliability of maze measures for rats, *J. Comp. Psychol.*, 1927, 7, 459.

[15] Tolman & Nyswander, *op. cit.*

One hundred and five Ss learned as their first main maze the maze which is designated as *M*. Conditions were the same for all. They give a mean of 19.5 trials and 42.9 errors, a median of 18 trials and 38 errors, and a mean variation (computed from the mean) of 8.3 for trials and 18.6 for errors. Seventy-three subjects learned *C* [16] as their first main maze under identical conditions. They give a mean of 19.6 trials and 44.5 errors, a median of 17 trials and 39 errors, and a mean deviation of 8.6 for trials and 19.8 for errors. These groups are divided into smaller groups according to what mazes they learned the second day or the second and third days. Both the mean and median are given for all groups. These two measures, with one or two exceptions which will be pointed out, are practically the same straight through.

The first group learned maze *M* two days in succession without being told that it was the same maze. The results for this group are given in Table I. Right hand is designated by *R* and left by *L*.

TABLE I

	M(*R*)		*M*(*L*)	
	Trials	Errors	Trials	Errors
Mean	20.2	42	7.7	10.7
Median	21	44	6	13

There were 15 Ss in this group, four of whom recognized the maze on their first or second trials. One of these four Ss was one of three mentioned above who learned two sets of mazes. This was the second set for this subject and may have been a factor in the recognition. Another S recognized the maze on his first perfect run, and thus did not profit by this recognition. A sixth became suspicious of the maze on his fourth trial, made two errors on the next trial and none thereafter, but ended by believing that the third and fourth moves in the maze were opposite to those in the maze learned the previous day. Three others were dimly aware of some similarity, but were no more aware of it than those subjects, for example, in Groups 5 and 6 who learned two mazes which were very dissimilar.

[16] Warden, *op. cit.* This same maze was used by Warden. With 30 Ss he got a mean of 69 trials and 183 errors. That the mean in the present experiment is so much lower is due mainly to the fact that the Ss were given one day's preliminary training.

Table II gives the results for another group of subjects who learned the same maze (*M*) both days with the right hand.

TABLE II

	M(*R*)		*M*(*R*)	
	Trials	Errors	Trials	Errors
Mean	18.2	40.1	8.3	12.7
Median	22	37	7	13

Four of the 15 subjects recognized the maze on the first trial. One other was vaguely aware of some similarity, but was not sure what it was.

A comparison between Tables I and II would seem to indicate that it makes no difference which hand is used the second day. Further proof of this will be given later on. Putting these two groups together, we get a group of 30 Ss giving means and medians as indicated in Table II*x*.

TABLE II*x*

	M		*M*	
	Trials	Errors	Trials	Errors
Mean	19.2	41	8	11.7
Median	21.5	42	7	13

When the 8 Ss who recognized the maze in time to profit by the recognition are taken out, the remaining 22 give means as indicated in Table II*y*.

TABLE II*y*

	M		*M*	
	Trials	Errors	Trials	Errors
Mean	22	46.4	9.4	14.5

These means are somewhat higher throughout. This would seem to indicate that these eight Ss were slightly better on *M* the first time than the other 22. It also shows that they learned *M* the second time more easily with recognition than the other 22 did without recognition. The important thing, however, is the fact that the means on *M* the second time for the other 22 are still relatively low. This point will be shown more conclusively when the results of the control groups are given.

Table III gives the results of a group which learned *M*

the first day and *M'* the second day, *M'* being the same as *M* except that the initial horizontal move is reversed, leading off to the right instead of to the left.

TABLE III

	M(*R*)		*M'*(*L*)	
	Trials	Errors	Trials	Errors
Mean	20	45.3	8.3	14.1
Median	16	45	8	12

Only one of the 15 Ss in this group was fairly sure that maze *M'* was the same as *M* except for the first move. He was not quite sure, though, and finally said that he thought the first, second, and possibly the third, moves, and not the first only, were different. One other S recognized some similarity, first stating that the maze had been turned around. He later decided that this was not correct, but couldn't state what the similarity was.

This group learned *M'* as easily as the other groups learned *M* the second time, yet only one S was particularly aware of any similarity between the mazes. The slight alteration in pattern evidently gave the maze a very different configuration. There was a tendency for Ss in learning *M* to be more impressed by certain sections of it than by others. This was true of the first two moves to the left and of the three moves to the right about the middle of the maze. These were small configurations which never completely lost their identity in a larger configuration. In *M'*, however, the configuration which took precedence was that of alternate moves, the first five moves in the maze being of such a nature. The last of these alternate moves was the first of the 'three-step' to the right, but most of the subjects thought of the maze as being composed of five alternate moves followed by two to the right, and not as being composed of four alternate moves followed by three to the right. This predominance of alternate moves in *M'* seemed to obliterate recognition, but did not seem to affect the memory of the pattern. The retention of the pattern probably was not affected for the obvious reason that all the moves in the two mazes except the first one were the same, and the points of choice, *i.e.*, the points

where a choice must be made between two directions, were exactly the same. The total configurations, however, were different, and this, as stated above, seemed to affect recognition more than it affected retention. In fact, this group, as far as retention of pattern is concerned, is so similar to Group 2-*y* that for purposes of later comparisons it can be combined with 2-*y*, giving a group of 37 Ss designated as Group 3-*x*. The figures for this group are given in Table III*x*.

TABLE III*x*

	M		*M* or *M'*	
	Trials	Errors	Trials	Errors
Mean	21.2	46.1	8.9	14.4
Median	19	45	8	13

The question of slight alteration was carried further, Group 4 learning, as their second maze, *D;* a maze, the first nine of whose moves are the same as the last nine in *M*, *i.e.*, *D* corresponded with *M* from the latter's third move (see Fig. 6 on page 194). Two moves were added to make it the same length. As Table IV shows, however, the pattern-effect seems to break down to a certain extent here, because *D* seems more difficult to Group 4 than *M'* did to Group 3. The increase in difficulty seems out of proportion to the increase in objective dissimilarity. None of the 17 Ss in this group noticed any similarity to speak of.

TABLE IV

	M(*R*)		*D*(*L*)	
	Trials	Errors	Trials	Errors
Mean	22.1	47.6	11.8	22.7
Median	21	46	12	21

That this increase in difficulty in Group 4 is out of proportion to the increase in objective dissimilarity is shown more conclusively by a comparison of Table IV with Tables V and VI. Groups 5 and 6 are the control-groups. Group 5 learned

TABLE V

	H(*R*)		*M*(*L*)	
	Trials	Errors	Trials	Errors
Mean	16	32.9	14	35.6
Median	15.5	31	10.5	24

two mazes, *H* and *M*, which are relatively very dissimilar, and Group 6 learned the same mazes but in a reverse order. There were 16 subjects in Group 5 and 13 in Group 6.

It is true that the mean here is very much higher than that for *D* in Group 4. The median is also somewhat higher, increasing from 21 to 24, and the median is the better measure in this group, particularly since two subjects were much poorer than the rest on *M* and raised the mean considerably. This rise in the median, however, from 21 to 24 is not in proportion to the increase in objective dissimilarity between *M* and *D* on the one hand and *H* and *M* on the other.

TABLE VI

	M(*R*)		*H*(*L*)	
	Trials	Errors	Trials	Errors
Mean	20.8	50.5	12.1	21.2
Median	18	37	12	22

When Group 6 is compared with Group 4 the results on the second maze are practically the same, and on this basis alone it would seem that the pattern-effect has completely broken down in Group 4. There is another factor, however, which must be considered here, and that is the fact that *H* [17] seems to be an easier maze than *M*. There are two reasons for believing *H* easier. First, the record for *H* as the first maze in Group 5 is considerably lower than the records for *M* as the first maze in Groups 1, 2, 3, 4 and 6. The mean of the errors for *M* as the first maze in these five groups is 45, whereas the mean of the errors for *H* as the first maze in Group 5 is 32.9, a difference of 12.3 errors. Secondly, the mean of the errors for *H* as the second maze in Group 6 is lower than the mean of the errors for *M* as the second maze in Group 5. This gives a difference of 35.6 − 21.2 or 14.4.

[17] R. W. Husband, Human learning on a four-section, elevated, finger maze, *J. Gen. Psychol.*, 1928, 1, 15–28. Husband found that the section of his maze which was the same as the mirror-reversal of our *H*-maze was the most difficult section of his four-section maze. He gives as the reason for this difficulty that *H* has more changes of direction, or fewer consecutive moves in the same direction, than the other sections. It would seem, however, that change of direction is not the sole cause of the difficulty of a maze. Maze-*M* has one less change of direction than *H* and is found to be more difficult.

This second difference, however, is probably too great, since, as has already been pointed out, the mean of the errors for *M* as the second maze in Group 5 was raised considerably by two Ss. These two Ss and probably one or two others seemed to have more than the average amount of difficulty with *M*, partly because they had been able to solve *H* with a rather unsystematic method of attack, and tried for some time to apply the same method to *M*. If these Ss had had a more difficult maze preceding *M*, they might have developed a better method of attack the first day, and because of this solved *M* more easily the second day. Since, then, *H* is easier than *M*, and since it is possible that *M*, in a few cases at least, was made more difficult in Group 5 because it was preceded by *H*, neither Group 5 nor Group 6 is as good a control group as might be wished. If these two groups, however, are combined, the influence of the position of the two mazes is cancelled to a certain extent, and a more valid control-group would seem to be obtained. These groups are combined as Group 6-*x* and are given in Table VI*x*. There are 29 subjects in this group.

TABLE VI*x*

	M & *H*		*M* & *H*	
	Trials	Errors	Trials	Errors
Mean	18.2	40.8	13.1	29.1
Median	16	36	11	23

A comparison of Group 4 with Group 6-*x* does not completely clear up the question as to what degree the pattern-effect is an element in Group 4. This comparison on the basis of means would seem to indicate that the pattern-effect is still a fairly important element in Group 4, while a comparison on the basis of medians would seem to indicate that this element is not so important.

That the pattern-effect, however, is an important factor in Groups 1, 2 and 3 is indicated by a comparison of these groups with Group 6-*x*. This comparison should be made between Table III*x* on the one hand, a table including only those subjects from Groups 1, 2 and 3 who did not profit from recognition of the maze, and Table VI*x*, on the other

hand. A comparison of both means and medians is given in Tables VIy and VIz.

TABLE VIy

	1st Maze		2nd Maze	
Means	Trials	Errors	Trials	Errors
Group 6-*x*	18.2	40.8	13.1	29.1
Group 3-*x*	21.2	46.1	8.9	14.4
Difference			4.2	14.7

TABLE VIz

	1st Maze		2nd Maze	
Medians	Trials	Errors	Trials	Errors
Group 6-*x*	16	36	11	23
Group 3-*x*	19	45	8	13
Difference			3	10

These tables show greater saving on the second maze for Group 3-*x* than for Group 6-*x* regardless of whether the saving is figured in terms of means or medians. This difference in saving, it seems, is due to the retention of the maze-pattern from one day to the next. It is true that a certain saving is derived from practice-effect on maze-running in general. This is evident from a comparison in Group 6-*x* of the results of the first maze with those of the second maze. The mean of the errors for this group is 40.8 for the first day and 29.1 for the second day, giving a difference of 11.7 errors. This average saving of 11.7 errors from one day to the next is due to the fact that this group on the second day had had, in addition to preliminary training, a day's practice in general maze-running, on a maze which was as dissimilar as possible, so far as pattern was concerned, but identical as far as units were concerned.

The difference in results, then, between Groups 3-*x* and 6-*x* on the second day is in addition to practice-effect, and as stated above is a difference or saving due to the retention and the unconscious functioning of the pattern which had been learned the previous day.

That this saving on the repeated maze does not come mainly on the first few trials, but is distributed evenly throughout the learning process, is indicated by a comparison

of the typical learning curves given in Fig. 2. Individual trials are given on the base line, and the mean number of errors for each trial on the vertical line. Group 6-*x* is the control and Group 3-*x* the test group. A comparison which

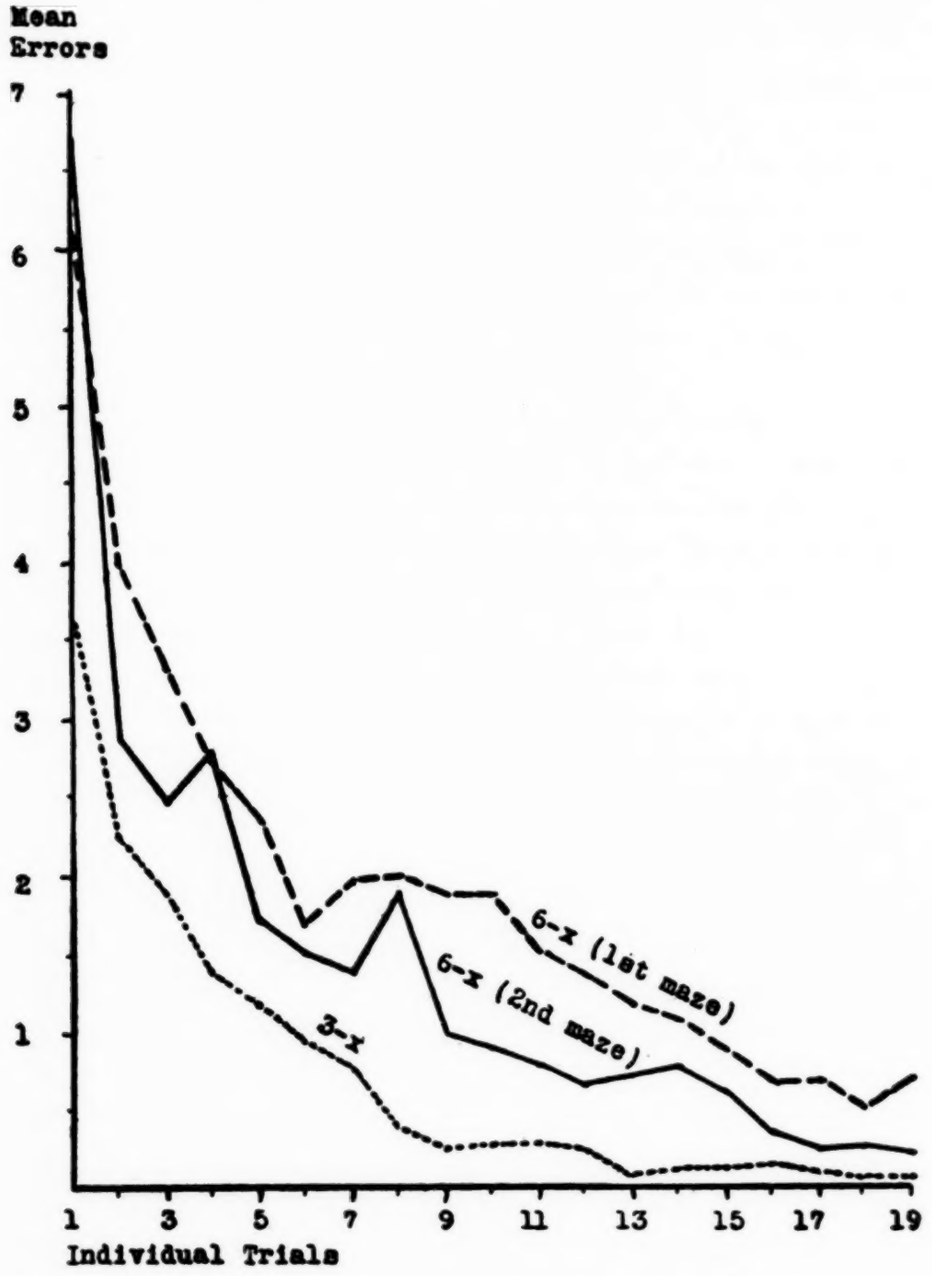

FIG. 2. Learning curves comparing practice-effect with effect of retention of pattern. The difference between curve 6-*x* (1st maze) and curve 6-*x* (2nd maze) is due to practice-effect, and the difference between curve 6-*x* (2nd maze) and curve 3-*x* is due to retention-of-pattern. This figure shows that the effect of retention-of-pattern is distributed evenly throughout the learning process.

shows the effect of the retention of patterns is that between 3-*x* and curve 6-*x* (second maze). The curve for 6-*x* on the first maze has also been included in this figure and a comparison between curve 6-*x* (first maze) and curve 6-*x* (second maze) shows clearly the saving due merely to practice.

Group 7 is of interest in connection with Group 4. Group 7 learned mazes *C* and *D*, *D* being a mirror reversal of *C*. As Table VII shows, the means and the medians on *D* are about the same for this group as for Group 4. This would seem to indicate that the help derived from learning a maze, nine of whose moves were the same as *D*'s and the help derived from learning a maze which was the mirror-reversal of *D* were about the same. Further, it would show, as has been pointed out above in connection with Group 5, that this help is of little consequence, and that the pattern-effect has just about broken down. Handedness is not indicated for maze *D* since half of the Ss did it with the right hand and half with the left.

TABLE VII

	C(*R*)		*D* (*R*, *L*)	
	Trials	Errors	Trials	Errors
Mean	17.4	40.1	10.9	21.2
Median	16	37	10	21

There were 37 Ss in Group 7, one of whom recognized *D* as the mirror reversal of *C*. Two other Ss had some suspicion on this point, but were not sure. One of the two, however, was almost sure, and seemed to profit by his suspicion. The one S who recognized the maze, and the one who was almost sure of it, change the results very little, so they will be left in for the present. A further analysis of this group will be given later on.

The question arose as to how many of the errors made by Group 3-*x* on *M* and *M'* as second mazes were due simply to forgetting. Group 8 answers this question. In Group 8 con-

TABLE VIII

	M(*R*)		*M*(*R*)	
	Trials	Errors	Trials	Errors
Mean	19.5	36.4	2.6	1.7
Median	18	32	2	1

ditions were similar to conditions in other groups except that just as the Ss were ready to start on *M* the second time they were told that it was the same maze. There were 13 subjects in this group.

There was an interval of four days between mazes in one of these cases and this subject required nine trials and ten errors to relearn *M*. This difficulty was due partly to the greater interval and partly to the fact that the S had a very erroneous idea as to what the maze was like. If this S is eliminated, the means are 2.1 trials and 1 error. These results would seem to indicate that there is very little forgetting of maze patterns over a period of 24 hours and that this is not a factor to be considered in comparing Groups 3-*x* and 6-*x*.

Another question which arose was just how much the subjects were profiting by the preliminary practice the first day; so Group 9 learned *M* the first day without seeing *Y* and without practice on *X*. There were 16 Ss in this group, one of whom did only the first maze. These results are given in Table IX.

TABLE IX

	M(*R*)		*M*(*L*)	
	Trials	Errors	Trials	Errors
Mean	24.1	64	7.3	12.6
Median	23.5	68	4	9

The one subject who did only the first maze was very poor, requiring 43 trials and 143 errors to learn the maze, and probably did not come back the second day on this account. If he is taken out, the means are 22.9 trials and 58.7 errors, and the medians are 23 trials and 63 errors. Eight of the 15 Ss finishing the maze recognized it.

These results are significant for several reasons. First, it took this group much longer to learn *M* the first time than it took any other group. Secondly, this group learned *M* the second time more easily than Groups 1, 2 and 3, with which it should be compared. This is particularly true when we consider the medians, the means being increased by two or three Ss. If we take out the subjects who recognized the

maze, however, as was done above in connection with Groups 1, 2 and 3, we get means for the remaining seven subjects as follows:

TABLE IX*x*

	M(*R*)		*M*(*L*)	
	Trials	Errors	Trials	Errors
Mean	23.3	59.4	8.9	17.4

These means on *M* the second time are still much lower than those obtained in Group 5, which are 14.3 trials and 36.1 errors. They are, however, slightly higher in errors than those given by the 37 Ss in Group 3-*x*, who did not recognize the maze. These means are 8.9 trials and 14.4 errors. There is no way of accounting for this slight difference in mean errors except that the 17.4 errors is an average of only seven cases and this is too small a number to give reliable results. The third fact about this group is that eight of the Ss recognized the maze, five of whom recognized it the first run, making no errors at all. Another S made two errors on the first trial, as he thought it would not be the same maze, but ran it perfectly the second trial and was sure that it was the same maze. The other two Ss had some suspicion on the first trial, but because of slight changes in methods, the maze did not 'feel' quite the same, stating that they thought it was the same maze but would not be willing to take oath to this effect.

This greater percentage of recognition is probably due to two factors; first, because this group had greater difficulty learning *M*, and most of the pattern was more over-learned than in the other groups; and secondly, because Group 9 had only one pattern while the other groups had two patterns in mind when they came to *M* the second time.

The nine tables given so far are summarized graphically for mean errors in Fig. 3. Only those Ss are included who did not recognize the maze in time to profit by recognition. The first or light column of each pair of columns represents the mean of the errors made on the first maze. The second or dark column represents the mean of the errors made on the second maze. The number of the groups is given underneath

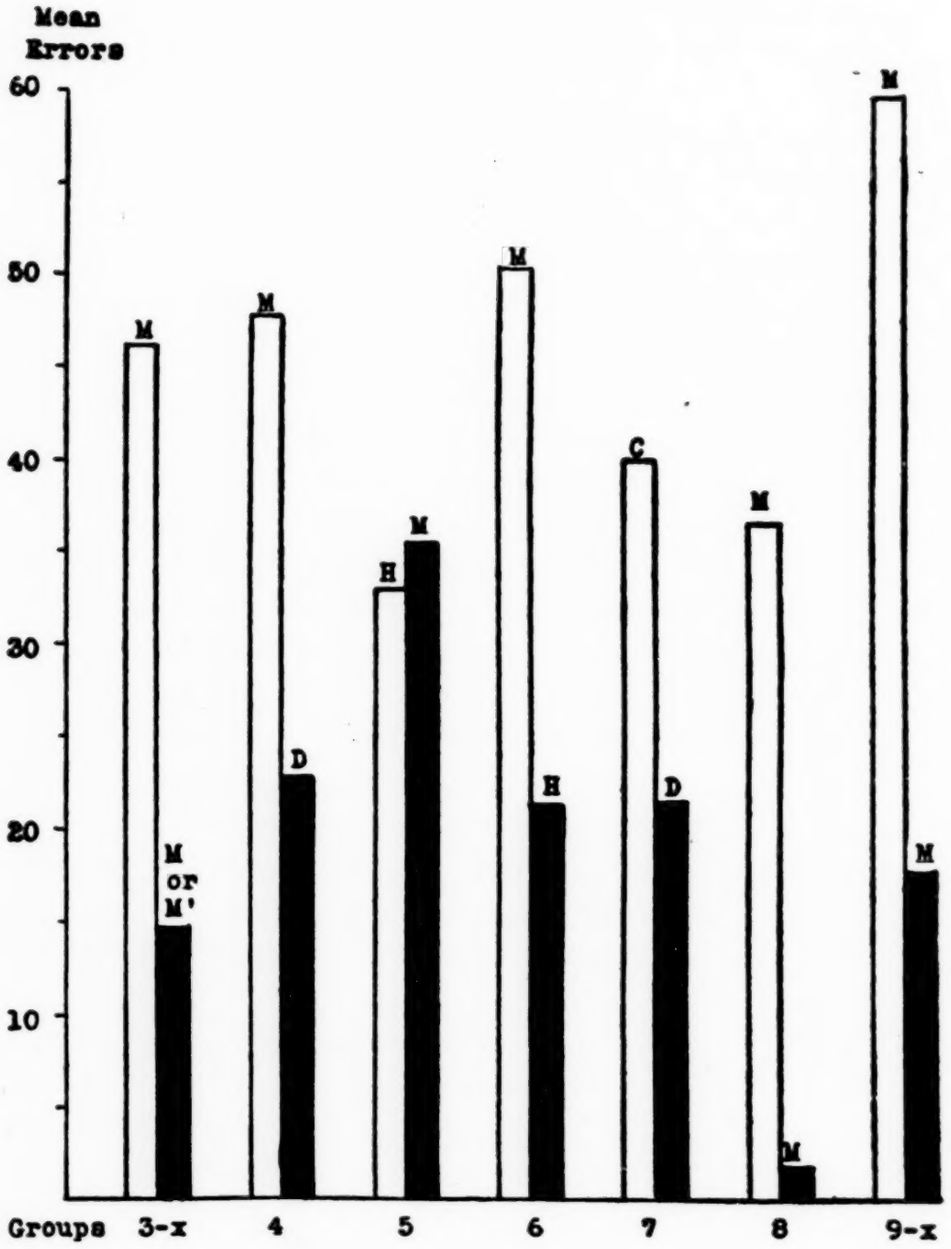

FIG. 3. Comparison of groups having mazes the second day of various degrees of dissimilarity from those of the first day, or having the first maze repeated under various conditions. Group 3-*x* had practically the same maze the second day. Groups 4, 5, 6 and 7 had mazes the second day of various degrees of dissimilarity. Group 8 was told the second day that the maze was the same. Group 9 had no preliminary maze.

each pair of columns, and the name of the maze is given at the head of each column. This figure shows somewhat more plainly the facts mentioned previously in connection with the groups or tables here summarized.

Group 10 learned, as their second maze, *N*, the same maze as *M*, except that the cross on the T is V-shaped rather than straight. In some cases the similarity of pattern seems to have helped, and in others it did not. In only two cases was a certain amount of similarity noticed, and in one of these cases the S was an instructor in the department who himself had done work with mazes and knew something of the problem under study. This group is mentioned mainly because shifting to *N* caused a change of imagery or method of attack, the most striking being a change from verbal to motor. Eleven of the 15 Ss in this group made a distinct shift to motor imagery in learning *N*. In a few of the cases, however, a complete change was made from verbal to motor imagery. In only one case did a pure verbalizer remain so when he learned *N*. There was one S who learned both mazes in a purely motor manner. In a few cases visual imagery became more prominent in learning *N*. The reason for this change mainly from verbal to motor imagery was the inability of the subjects to analyze the maze into units. They had to depend upon general direction and arm-feeling. The results of this group are given in Table X. They show *N* to be a fairly difficult maze.

TABLE X

	M(*R*)		*N*(*L*)	
	Trials	Errors	Trials	Errors
Mean	15.5	38	22.3	58.7
Median	15	31	19	45

Fourteen Ss from Groups 1, 2, 8 and 9 found their last day's task so easy that they wanted to do a more difficult maze. They were given *N* immediately after having finished *M* the second time. These Ss were somewhat better than average, else they would not have found their last day's task so easy. They average, however, very little better on *M* than Groups 8 and 10, and these latter were not picked groups.

Their results are given in Table XI, and it will be seen that they did very much better on *N* than Group 10 did. Eight of these Ss, either on their first run or their first perfect run, recognized a certain amount of similarity between *N* and *M* and learned *N* easily, four others learned *N* easily but reported no recognition, and two learned *N* with difficulty and were unaware of any similarity whatsoever. This group showed a less radical change in imagery and mode of attack than Group 10, most of the Ss being able to use the same method in *N* as in *M*. The verbalizers, as it seems, were able to analyze *N*.

The reason why these Ss had little difficulty as a group with *N* is probably due to two factors; first, having worked with *M* for two days, they had it more thoroughly learned than Group 10 did; and secondly, they had more of a mental set for some such task as this than Group 10 had. This set was due to the fact that those coming from Group 8 had been told when working under Group 8 that *M* was the same the second day, and all those coming from Groups 1, 2 and 9, except one, had recognized *M* the second time. The results of these 14 subjects are given in Table XI.

TABLE XI

	M(*R*)		*N*(*L*)	
	Trials	Errors	Trials	Errors
Mean	16.1	34.4	10.3	25.5
Median	16	27	8.5	19.5

In Fig. 4, Groups 10 and 11, together with Group 3-*x*, are shown graphically on the basis of mean errors. Group 3-*x* is given for basis of comparison. As in Fig. 3, the first or light column of each pair of columns represents the mean errors made on the first maze; the second or dark column represents the mean errors made on the second maze. The number of the groups is given underneath each pair of columns and the name of the maze is given at the head of each column. The difference between Groups 10 and 11 in the difficulty of learning *N* may be readily seen in this figure.

The rest of the groups learned three large mazes and all the groups except two started with the maze designated as *C*

and ended with it, each group having a different maze in between. Groups 12 and 13 have the maze *D* in between. This maze, which was also used in Group 4, and nine of whose moves are identical with nine of those of *M*, is the mirror reversal of *C*. The only difference between these groups is that in Group 12 all three of the mazes are learned with the

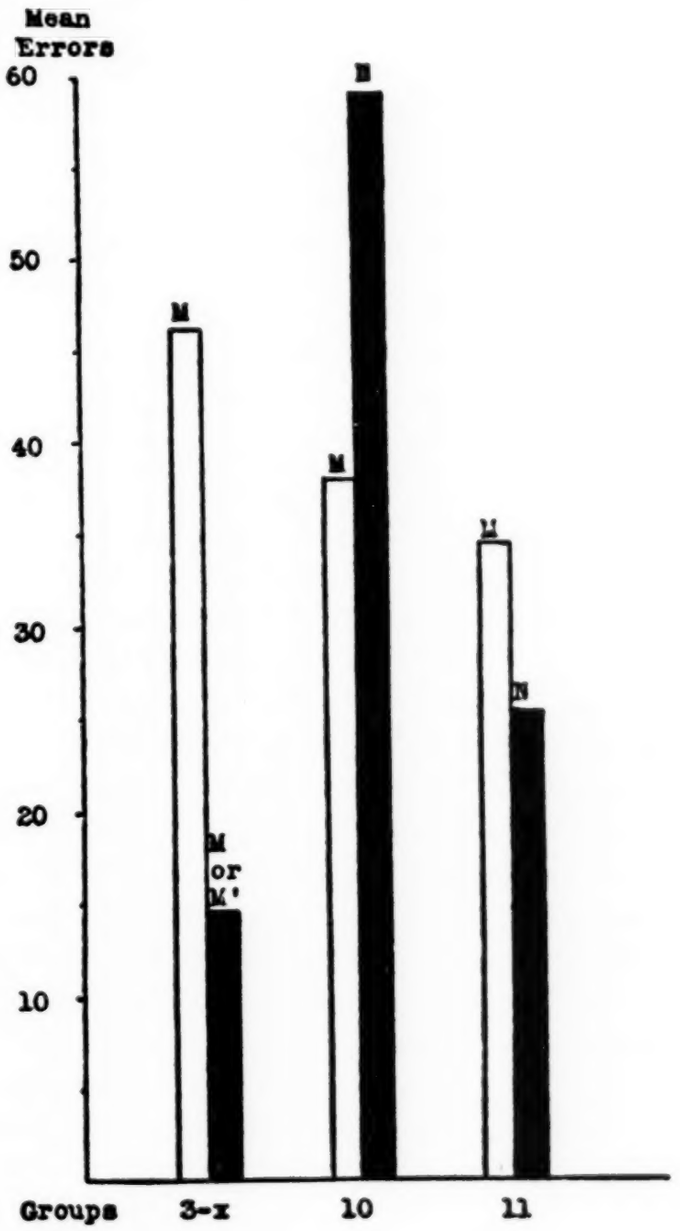

FIG. 4. Comparison of Groups 10 and 11 which learned *N* the second day under different conditions. Group 11 was a picked group and had greater knowledge of the problem than Group 10.

right hand, while in Group 13, *C* is learned both times with the right hand and *D* is learned with the left.

TABLE XII

	C(*R*)		*D*(*R*)		*C*(*R*)	
	Trials	Errors	Trials	Errors	Trials	Errors
Mean	17.4	40.3	10.9	20.2	7	12.5
Median	16	36	10	20.5	7	11

There were 18 Ss in Group 12, but five of them did not do the last maze. One had some slight suspicion as to the similarity of the mazes, but did not seem to profit by it. Quite a number of the subjects, not only by their objective results, but also by their behavior,[18] showed that the patterns had been retained to a certain extent over the interval of the *D*-maze learning.

TABLE XIII

	C(*R*)		*D*(*L*)		*C*(*R*)	
	Trials	Errors	Trials	Errors	Trials	Errors
Mean	17.4	40	10.9	22.1	7.8	13.8
Median	16	40	10	22	8	13

Six of the 19 Ss in Group 13 did not do the last maze. One knew that *D* was the mirror reversal of *C* and another was almost sure of it. The first of these two Ss recognized *C* as the same maze he had learned the first day. Both subjects seemed to profit by the recognition. One other recognized *C* as the same maze on his first perfect trial and still another had some suspicion of this similarity. This group showed about the same amount of retention as did Group 12. A few Ss, however, in both Groups 12 and 13, showed signs of some interference [19] on the last maze. It is also evident from a comparison of the results for both *D* and *C* that handedness was not a factor in learning.

[18] This retention of pattern was evident from the fact that these Ss, after making one or two correct moves, would noticeably increase their speed. These movements were quite different from the hesitant, exploratory type of movements in evidence when the pattern had not been retained.

[19] This interference was more evident in the last half of maze *C*, and consisted in making rapid two-step movements, but in the direction correct for *D*. These movements, as pointed out before, were not the hesitant, exploratory type, but were quick and confident as though S knew where he was going.

These groups are so similar that they might be thrown into one group of 37 Ss, 26 of whom finished all three mazes. These 37 have already been reported on the first two mazes in Group 7. Table VII with the third maze added is repeated here as Table XIII*x*.

TABLE XIII*x*

	C		*D*		*C*	
	Trials	Errors	Trials	Errors	Trials	Errors
Mean	17.4	40.1	10.9	21.2	7.4	13.2
Median	16	37	10	21	7.5	12

If the two Ss who profited by recognition are thrown out, results are obtained as set forth in Table XIIIy. These results are practically the same as those in Table XIII*x*.

TABLE XIIIy

	C		*D*		*C*	
	Trials	Errors	Trials	Errors	Trials	Errors
Mean	17.1	38.1	11.1	21.8	7.8	13.6

It might be thought that quite a bit of the saving from *C* to *C* was due simply to practice-effect and not to pattern-effect. To test this it was decided to have Group 14 do three mazes which were fairly dissimilar, *C* being the third. The unit system, however, of all three mazes was the same.

TABLE XIV

	A(*R*)		*H*(*L*)		*C*(*R*)	
	Trials	Errors	Trials	Errors	Trials	Errors
Mean	20.7	45.7	15.8	30.9	6.4	11.7
Median	19	41	15	27.5	6	10.5

There were 12 Ss in Group 14 and their record on *C* was slightly better than that of Groups 12 and 13, showing that if there is any difference the similarity in pattern in Groups 12 and 13 must be a slight hindrance. The low record for *C* in Group 14 is due, so far as can be seen, entirely to practice-effect on T-type mazes. Judging from the objective results, it cannot be maintained that the low average for *C* the third day in Groups 12 and 13 was due to anything except this same practice-effect. As stated above, there was qualitative evidence of retention of pattern in some cases, and qualita-

tive evidence of interference in others; but the objective results in comparison with those of Group 14 give evidence for nothing except this practice-effect. It would seem, then, that when a second maze of the same general type is learned between the learning and the relearning of a maze, practice-effect overshadows and is more important than the effect produced by the retention of the pattern, or by the interference of the pattern of the repeated maze.

It should also be noted how much more difficult *H* seems in this group than in Group 6, where the means are 12.1 . . . 21.2 and the medians 12 . . . 22. This greater difficulty may possibly be due to the fact that, of the eleven moves in *H*, five successive moves about the middle of the maze are exactly the same as the five corresponding moves in *A*. This is shown in Fig. 5. This similarity may be more disturbing

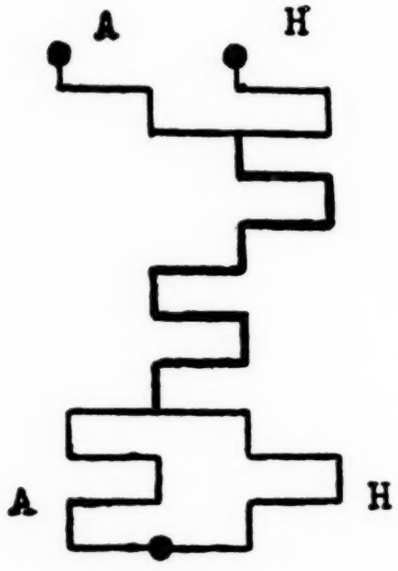

FIG. 5.

than helpful. If two maze patterns are so dissimilar that they can be learned as two distinct patterns, the second would seem to be learned more easily than if it is similar enough to call up the first pattern and thus set up a habit-interference.

In order to make a further test of the pattern-effect of *C*, in comparison with that of mere practice-effect, three other groups were run, starting with *C* and ending with *C*. The

first of these, Group 15, learned *C*, *H*, *C*, and in addition to testing the pattern-effect of *C*, throw some light on the difficulty of *H*.

TABLE XV

	C(*R*)		*H*(*L*)		*C*(*R*)	
	Trials	Errors	Trials	Errors	Trials	Errors
Mean	25.3	55.3	13.6	22.8	6.5	11.9
Median	24.5	49	11	20	5	10

There were 12 Ss in Group 15 and none of them recognized *C*. They seem to do *C* slightly more easily the second time than Groups 12 and 13, and with about the same ease as Group 14. This is further proof that the low record on *C* the third day is due almost entirely to practice-effect and not to retention of the *C*-pattern.

Group 15 also does *H* more easily than Group 14 and with about the same ease as Group 6, a fact which substantiates the reason given for the greater difficulty of *H* in Group 14. Maze *C* also has several moves which are the same as the corresponding moves in *H*, but no more than three are successive; whereas, in the case of *A* and *H*, five identical moves were successive.

Group 16 learned mazes *C*, *W*, *C*. *W* is the same as *D* except that like *N* the head of the T is V-shaped.

TABLE XVI

	C(*R*)		*W*(*L*)		*C*(*R*)	
	Trials	Errors	Trials	Errors	Trials	Errors
Mean	17.9	39.9	32	62.4	8.2	16.5
Median	17.5	38.5	27	48	8	15.5

There were 12 Ss in Group 16, 4 of whom recognized *C* the second time it was given. Only one of these subjects, however, recognized the maze on the first run, the other three becoming somewhat aware of the similarity on the last run in which they made errors and being sure that it was the same maze on their first perfect run. One other S had some slight suspicion of similarity, but was not quite sure what it was. If the one S who recognized the maze in time to profit

by the recognition is thrown out, the remaining eleven give results as indicated in Table XVI*x*.

TABLE XVI*x*

	C(*R*)		*W*(*L*)		*C*(*R*)	
	Trials	Errors	Trials	Errors	Trials	Errors
Mean	17.7	39.6	32	62.5	8.6	17.6

It should be noted that in this group there is an increase in trials and errors on *C* the second time, *W* seeming to offer less opportunity for practice than the intervening mazes in the preceding groups. The reason for this fact is that *W* is an entirely different type of maze. It would be possible to account for this poorer record on *C* as being due to a greater interference of the retention of the *C* pattern by *W* than by the more similar maze *H* in Group 15. Since, however, the records of Groups 12, 13 and 15 have been satisfactorily interpreted as being due primarily to general practice-effect on T-type mazes and not to the effect of retention-of-pattern, it is more probable that a similar interpretation is correct here, and that *W*, which is a V-type maze, has interfered with the practice-effect on T-type mazes.

Another comparison which might be noticed in passing is that between *W* in Group 16 and *N* in Group 10. *N*, it will be recalled, is the same as *M* except that the head of the T is V-shaped, and *W* is the same as *D* with the same exception. Both mazes are given as the second of the series, *N* following *M* and *W* following *C*, which is the mirror-reversal of *D*. This comparison is given in Table XVI*y*.

TABLE XVI*y*

	Means		Medians	
	Trials	Errors	Trials	Errors
Maze *N*	22.3	58.7	19	45
Maze *W*	32	62.4	27	48

There is not much difference in errors on these two mazes; but the difference in trials is quite impressive, there being a difference of 9.7 trials on the basis of means, and of 8.0 on the basis of medians. This difference is probably due to a

greater carry-over of the pattern from *M* to *N* than from *C* to *W*.

The shift of imagery or method of attack, which has already been pointed out in connection with *N*, was also evident in the learning of *W*, the most pronounced shift being from verbal to motor. There was also a pronounced shift back to verbal imagery on the last day when *C* was relearned, only two Ss depending mainly upon motor imagery. These two used the motor method straight through.

Group 17 learned mazes *C*, *E*, *C*. *E* is a regular T-type maze with a circuitous path of 18 units. This is another case where there is a great difference between the median and the mean, and the median is probably more reliable, particularly in the case of the first two mazes, since these means were raised considerably by two or three subjects.

TABLE XVII

	C(*R*)		*E*(*L*)		*C*(*R*)	
	Trials	Errors	Trials	Errors	Trials	Errors
Mean	22.8	52	10.7	56	7.7	14.3
Median	16	35	10	30.5	6	10

There were 12 Ss in Group 17, one of whom recognized the maze. Another subject recognized some similarity, but was never quite sure just how similar the two mazes were. With this subject out, the means are as given in the following table.

TABLE XVII*x*

	C(*R*)		*E*(*L*)		*C*(*R*)	
	Trials	Errors	Trials	Errors	Trials	Errors
Means	23.8	54.6	11.2	59.5	7.8	15.1

The record for this group is slightly better on *C* the second time than the corresponding record for Group 16-*x*, showing that *E* has a slightly less disturbing effect upon practice than *W*. The reason for this is believed to be due to the fact that *E* is a simpler maze than *W* and is learned with less effort. The greater simplicity of *E* is not so evident from a comparison of the mean errors on *E* and *W*, but it must be remembered that *E* has 18 culs-de-sac while *W* has only 10. This makes

it possible for many errors to be made on *E* on the first few exploratory runs. A comparison of the mean number of trials for *E* and *W* gives a better indication of their relative difficulty. This comparison is greatly in favor of *E*, *E* requiring a mean of 10.7 trials and *W* a mean of 32 trials. This greater difficulty of *W*, it seems, would cause it to have a greater disturbing effect upon practice. The means, however, for Group 17-*x* on *C* the second time are still somewhat higher than those for Groups 13-*y*, 14 and 15, showing that the practice on *E* is not as helpful as the practice on *D* and *H*, which were used as intervening mazes in these latter groups.

The thing to be noted about this group, however, is the fact that just as in Groups 6 and 16 there is a rather pronounced shift in imagery when changing from one type of maze to another. Visual and kinæsthetic imagery seemed to predominate and seemed to be most economical in learning maze *E*. This is a change from the predominately verbal and kinæsthetic imagery in learning *C*. Nine of the 12 Ss used a combination of visual and kinæsthetic methods, with some slight help from verbal cues, in learning *E*, and averaged about 30 errors. Two Ss, one making 107 and the other 110 errors, were extreme verbalizers and learned *E* as they did *C* in terms of rights and lefts. The other S learned *E* as he did *C* in a motor manner, but was very much confused by the circuitous path, making a total of 190 errors on *E*. He seemed to get very poor cues from his kinæsthetic sensations, but depended entirely on them, using no visual and no verbal imagery. The Ss who did best on this maze depended largely on visual imagery, with motor and verbal as aids. They spoke of the maze as having a very symmetrical, a very outstanding pattern, and saw it as so many blocks of city streets or blocks that children play with; and some saw it as a peculiar animal with two humps on its back. Maze *E*, more than *W* above, seemed to affect the imagery used in learning *C* the second time, several of the Ss using visual imagery the last day to a greater extent than the first day.

Group 18 learned the same mazes as Groups 12 and 13, that is, *C*, *D*, *C*, but with instructions as to type. The Ss

were told the first day and reminded each day before starting the maze that all the mazes were of the T-type and that all were built on exactly the same unit-system with the same proportions, etc.

TABLE XVIII

	C(*R*)		*D*(*L*)		*C*(*R*)	
	Trials	Errors	Trials	Errors	Trials	Errors
Mean	12.7	24.1	9.3	17.1	5.4	7.6
Median	12	25.5	8	15.5	3	5

There were 10 Ss in Group 18; but one did not do the last maze. Two of the nine recognized *C* the second time, and one of these two recognized *D* as the mirror-reversal of *C*. Another S recognized *D* as the mirror-reversal of *C* about an hour after learning *D*. He also recognized *C* as the mirror-reversal of *D* on his first perfect trial. If the results of the two Ss who recognized *C* and *D* in time to profit by the recognition are thrown out, the other seven give the following results.

TABLE XVIII*x*

	C(*R*)		*D*(*L*)		*C*(*R*)	
	Trials	Errors	Trials	Errors	Trials	Errors
Mean	12.8	22.9	10.8	19.9	6.1	8.9

These results are somewhat lower all the way through than the results for Group 13-*y*, but the difference is most noticeable on the first maze, the mean error dropping from about 40 to about 23. Instruction, then, affects the learning throughout the series, but affects it most on the first maze.

Thirteen of the 17 Ss in Group 4 repeated *M* after having done *M* and *D*. Table IV with this additional information is repeated as Table XIX.

TABLE XIX

	M(*R*)		*D*(*L*)		*M*(*R*)	
	Trials	Errors	Trials	Errors	Trials	Errors
Mean	22.1	47.6	11.8	22.7	5.9	9.2
Median	21	46	12	21	5	7

None of the Ss recognized the maze. One had a slight suspicion, but this suspicion came with his first perfect trial. This group gives the lowest figures obtained on a third maze

with the exception of Group 18, and Group 18 isn't comparable because of differences in instruction. These figures, however, are just what one would expect from the similarity of the two mazes, except that the drop from *M* to *D*, as was pointed out in connection with Table IV, is not in proportion to the objective similarity of the two mazes. The pattern-effect from *M* to *D* seems to break down to a certain extent. The drop from *D* to *M* on the other hand, as is shown by a comparison with Group 14, is slightly more than can be accounted for merely on the basis of practice-effect. The pattern, however, which is functioning the third day is probably the *D*-pattern of the previous day and not the *M*-pattern of the first day. The reason why the *D*-pattern seemed to have more effect on the third maze than the *M*-pattern has on the second maze may be seen from a study of the patterns of these two mazes as given in Fig. 6.

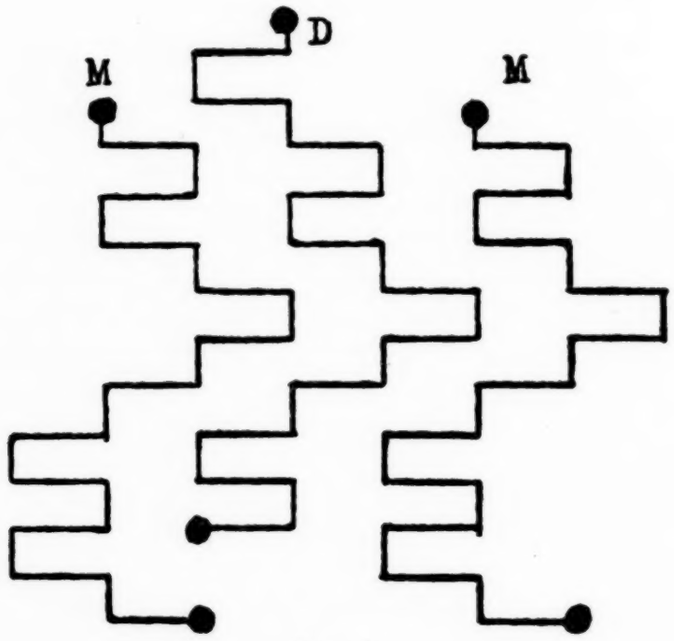

FIG. 6.

Even though the objective similarity of *M* and *D* is obviously the same as that of *D* and *M*, the subjective similarity is not the same. When S changes from *M* to *D* he is confused not only by the fact that he has to learn two new moves at the end of *D*, but also by the fact that the first

moves in *D* are not the same as the first moves in *M*. In other words, there is confusion at both ends of the maze and the amount of the pattern which can possibly function is less than nine moves. When, however, S changes from *D* to *M*, granting that it is the *D*-pattern and not the *M*-pattern which is functioning, there is confusion only at the beginning and from there on the moves are the same as the old pattern. No confusion results from the fact that the goal is reached before the old pattern has been completed.

Groups 12 to 19, inclusive, are summarized graphically in Fig. 7 on the basis of mean errors. As in Fig. 3, only those Ss are included who did not recognize the maze in time to profit by recognition. Group 17 learned *E* the second day, a maze having 18 culs-de-sac. The results for this maze have been modified in this diagram so as to make it comparable to a maze with 10 culs-de-sac. This was done by computing 10/18 of the average errors for *E*.

The first columns are shaded for all those groups which began and ended the series with *C*. Group 19, which began and ended the series with *M*, has the first column doubly shaded. Group 14, the one group which did not repeat a maze, does not have the first column shaded. The third column in each series, the one which should be compared, is made solid black. The number of the group is given underneath each set of columns, and the name of the maze is given at the head of each column.

This figure shows somewhat more plainly than the tables which it summarizes that the learning of the *C*-pattern the first day is not of great help in relearning it the third day. There are individual cases where it was quite evident behavioristically, as has already been pointed out (page 186), that the retention of the *C*-pattern did help, just as there are individual cases where it was evident behavioristically that this retention was a handicap. The mean for *C* the second time seems, however, to be slightly higher for those groups which had had *C* before than for Group 14, which had not had *C*. This forces the conclusion, as stated above, that the drop in the mean of *C* the third day is not due to retention of

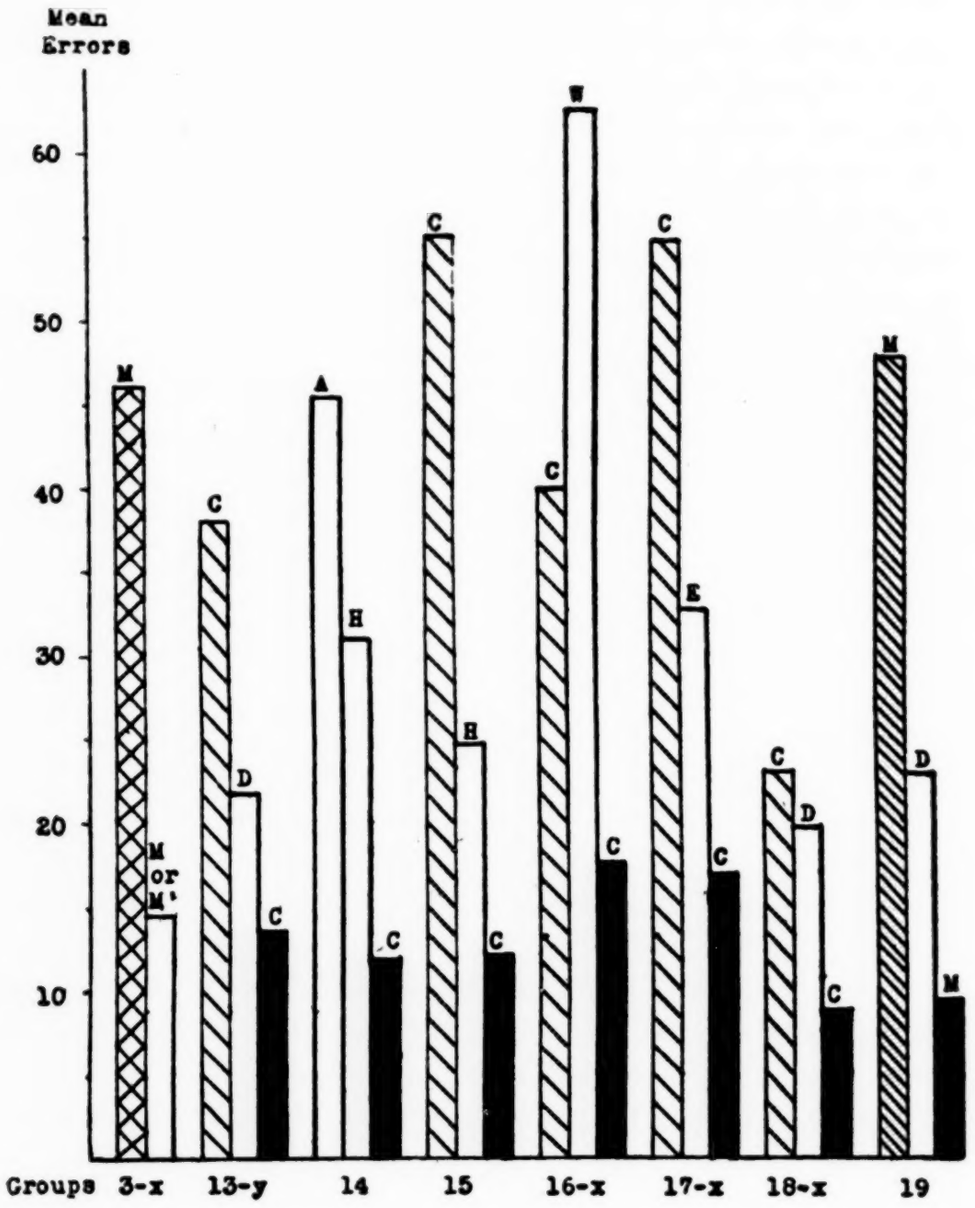

FIG. 7. Comparison of groups on their third mazes showing that practice-effect is more important in three-day groups than effect due to retention-of-pattern. Group 14 learned three different mazes and is the control group. Groups 13-*y* and 15 repeated the first maze on the third day but give about the same results the third day as Group 14. Groups 16-*x* and 17-*x* learned mazes of a dissimilar type the second day and give results the third day which argue for an interference of practice-effect. Group 18-*x* learned the same mazes as Group 13-*y* but was instructed as to type of maze being used. Group 19 offers evidence for retention-of-pattern but maze *D* is quite similar to maze *M*, and the results the third day may be due to the retention of the pattern of the second maze and not of the first maze.

pattern, but is probably due merely to practice-effect from maze-running in general. Group 19 gives some slight evidence to the contrary, but here the maze learned in between was very similar to the repeated maze, and the pattern which is functioning the third day, as pointed out above, is probably that of the second maze and not that of the repeated maze. Retention of pattern, then, from one day to the next and not from the first to the third day, seems to have been a factor in this group in addition to mere practice. An analysis of the figure shows that practice on an entirely different type of maze is not so helpful as practice on a maze having the same kind of units as *C*. Groups 13-*y*, 14 and 15, which had intervening mazes with the same type of units as those of *C*, learned *C* with fewer mean errors the third day than did Groups 16-*x* and 17-*x* which had different intervening mazes.

It is also seen from the figure (7) that the mean of the errors for each of the mazes of Group 18-*x* is lower than for the corresponding mazes of the other 'three maze' groups. This is the group which was instructed as to the type of maze being used. Groups 13-*y* and 19 learned *D* as the second maze and show very little difference on this maze. Groups 14 and 15 learned *H* as the second maze and show a great difference on this maze. These comparisons, however, have already been discussed.

Group 3-*x* has been included for the purpose of comparison, and here as in Fig. 3 the mean of the errors is lower on the second maze than that on the second maze in any other group, regardless of the fact that *M*, the second maze learned, is evidently more difficult than the second maze learned by some of the other groups.

Fig. 7 is made somewhat clearer by the learning curves given in Fig. 8. For the sake of simplicity the results of certain of the groups under discussion have been combined in the latter figure. Groups 13-*y*, 14 and 15, which learned intervening mazes of a type similar to their first and third mazes, and whose mean errors on the third maze are about the same, have been combined. Groups 16-*x* and 17-*x*, which

learned a dissimilar intervening maze and whose mean errors on the third maze are higher than those of the above groups, have likewise been combined. Groups 18-*x* and 19-*x* have been included, the first showing practice plus knowledge as to type of maze, and the second showing practice plus reten-

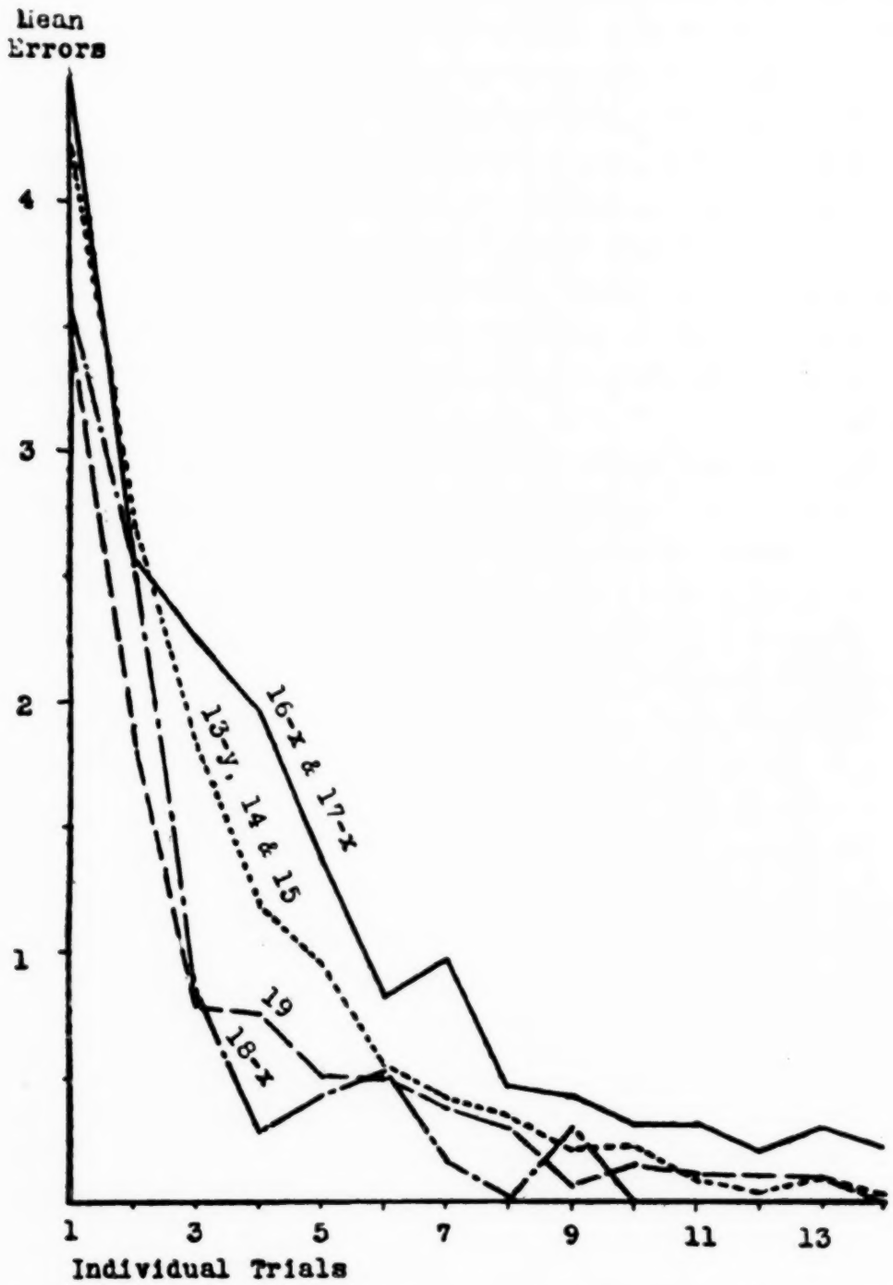

FIG. 8. Learning curves which show that the differences which were pointed out in connection with Fig. 7 do not occur at one place in the curve, but are consistent throughout. For further explanation see explanation of Fig. 7.

tion of pattern of the maze learned the previous day. These are typical learning curves and they show that the differences which were pointed out in connection with Fig. 7 do not occur at a single place in the curve, but are rather consistent throughout.

Qualitative Discussion of Recognition

Recognition seems to be largely a question of mental set. If the subject is perfectly naïve, he does not, as a rule, recognize a repeated maze. In many cases when the mazes were recognized, it was because the Ss had wondered what the object of the experiment was and had thought, among other things, that the mazes might be repeated. This would probably account for something like a third of the thirty-odd subjects who either recognized mazes or were aware of some similarity. Five Ss coming from Group 9 had had a great amount of difficulty with the first maze and had decided not to try to learn a completely new pattern, but to follow the old pattern as far as it was correct and merely make necessary changes. It is needless to say that these five Ss ran the maze perfectly the first time. Three of the Ss who recognized *D* as the mirror-reversal of *C* said that the mere change of hands caused them to think that the second maze might be the opposite of the first. The probability of this is borne out by the fact that there was considerably more suspicion in Group 1 which changed from right hand to left than in Group 2 which used the right hand on both days. Another S became suspicious of *D* largely because the first move was opposite that of *C*. Two Ss who were aware of some similarity were so impressed with the first maze that they drew it after returning to their rooms and had thought about it a great deal before doing the second maze. Two others from the 'two maze' groups tried to leave the entrance in the direction opposite to the correct direction. Since the exit from the entrance led off in the same direction as the one on the previous day, it occurred to them that it might be the same maze. They got their cues from the fact that the exits from the entrances of the two mazes they had had led off in oppo-

site directions. Several Ss admitted that on the way to the laboratory they had tried to recall the maze they had had the previous day and some of them asked during the course of the experiment if mazes were ever repeated. One asked this just as he was starting the second maze, which was a repeated maze. This particular S had some suspicions but was never quite sure, however, that the maze was the same. Several others had a former pattern quite well in mind when they started a maze and consciously made errors thinking that the mazes would not be the same. After an error or two they decided to follow the old pattern, and thus recognized the maze. Others, however, seemed to have a former pattern equally well in mind and consciously made errors, but became engrossed in their errors and forgot all about the former pattern. A striking example of this is the S in Group 1 who has a total of one error on *M* the second time. He said he was aware that the first move of the second maze was the same as that of the first and that he consciously made the second move opposite that of the first maze. This error, however, disturbed him to such an extent that, even though he made no more errors, he had not the slightest idea that the mazes were the same.

A few Ss, however, who recognized the maze or were aware of some similarity, seemed to have this recognition or feeling of similarity aroused purely by kinæsthesis. Two spoke of having irresistible impulses to follow a certain pattern through the maze, unaware at the time that the pattern was that of the former maze. Recognition came, as a rule, somewhat more slowly in these cases and seemed to be based entirely on these motor feelings. In summary then, recognition, as stated above, depends as a rule largely upon mental set.

Qualitative Discussion of Retention

So far the retention of patterns in maze learning has been discussed largely from the quantitative side. The qualitative aspect, which is not so easily shown, is even more evident to the experimenter as he watches subjects relearn mazes. Most

of them make the first few trials somewhat blindly to get the general direction or the general pattern of the maze. This generally results in one or two of these first few runs on a repeated maze being very good. Some relearn the mazes in this manner without any effort whatsoever. This was particularly noticeable in the case of a few Ss who had planned to follow this general idea of the maze with a detailed idea built up by memorizing turns. They found the maze so easy that they did not have to memorize turns. They knew it without memorizing. Others, however, either had to, or chose to take this second step and memorized turns. As a rule, they show an increase in errors on the trial where memorizing began, implying that memorizing interferes with kinæsthesis. Many Ss remarked that it was very easy to spoil a run by thinking too much or trying too hard, and that the best results were obtained with a moderate degree of effort. The fact that most of these drop rather low in errors on at least one of the motor exploratory trials, before beginning cautiously to build up the pattern step by step, cannot be shown quantitatively because of overlapping, the good run varying from the first to the fourth.

Further evidence for the retention of patterns is the fact that many Ss, who had been extremely cautious on their first trials on the first maze and who had planned to be slow and cautious on their first trials on the second maze, found themselves plunging ahead more rapidly than they wished. Several showed great surprise and a certain amount of chagrin at this, feeling that they had run entirely too fast to remember the sequence of moves. One remarked after his first trial that he didn't know where he was going, but that he was certainly 'on his way.' This bit of slang aptly describes the phenomenon. Two other Ss spoke of having strong motor feelings, what they called irresistible impulses to swing through a certain pattern.

A similar phenomenon is the fact that most Ss would speed up after getting one or two moves of a repeated maze correctly. This speed often carried them into a blind alley, but it gradually increased until a block was met. An especial

case illustrating this point is that of the S already referred to in Group 1 who made only one error. This error was made on the first alley, and from here on to the goal he ran with gradually increasing speed.

More evidence can be shown for the retention of patterns by a discussion of the remarks of certain typical individuals. One S was very much pleased and surprised at the ease of the first run. When she had finished the maze, she asked why she was able to make the runs so easily, and added jokingly that the experimenter must have been exerting some kind of mental influence over her, leading her in the right direction. The feeling of pleasantness and the surprise at the ease of the first run was a common phenomenon. Another S insisted that he learned the second maze intuitively. He said that he didn't memorize turns, didn't visualize the pattern or do anything which required any concentration. In fact, he said that he hardly thought about the maze at all as he did it. Many other Ss described a similar reaction. One said that he used very little reasoning on the second maze. Two who had largely depended on verbal imagery the first day found it unnecessary the second day, stating that the maze was too easy to require it. Another was utterly bewildered by his first perfect run, and said that he didn't have the slightest idea how he did it; there was something rather uncanny about the last maze to him. Several reported that they did not thoroughly learn the last maze. They did it just by pushing ahead, or the movements weren't very clearly in mind but unrolled before them as they made them, one movement calling up another. Several ascribed their first perfect run on the second maze to pure luck, stating that they did not know the maze. One stated that the last maze was so easy that most of it required no thought whatsoever, and thus it was easier to concentrate on the one or two difficult spots. Several used a guessing scheme in learning the first maze, deliberately trying to outguess the constructor of the mazes. One of these got the three-step in *M* correctly the first time. He was a man with football experience and stated that he made these three moves in succession in the same direction

thinking that it was poor policy as a rule to try the same play three times in succession in football, but that sometimes it was highly successful. The second day this S got the three-step again on the first trial and said he was dimly aware of what he was doing, but did it without any deliberation. He had a total of two errors on *M* the second time and was totally unaware of any similarity.

Kinds of Imagery Involved and the Relative Value of Each

It is difficult to classify subjects in this experiment on the basis of the types of imagery involved, the reason being that very few Ss adopted one type of imagery and held to it throughout the experiment. In fact, very few used one type of imagery exclusively throughout the learning of even the first large maze. Of this small group only one S could be called a pure verbalizer on the first maze, and the rest of them learned the maze purely in a motor manner. This one visualizer has the lowest record for trials and next to the lowest for errors of the 230 Ss, while the few who used kinæsthetic imagery entirely have a very high average for both trials and errors.

Most Ss began, as a rule, the first maze in a motor manner and gradually combined this method either with verbal, or in a few cases with visual imagery, and it was the impression of the writer that the total number of errors stood in direct relation to the length of time which elapsed before a decided shift was made to verbal imagery. That is to say, the sooner the shift to verbal imagery, the fewer the errors made.[20]

The Ss who learned the first maze with a combination of kinæsthetic and visual imagery seem to be better than the extreme motorists, but worse than those who did a certain

[20] The shift to verbal imagery was never complete. While the Ss were learning the first part of the maze in a verbal manner, they were learning the last part in a motor manner, so that they really did not need to verbalize the whole maze. It is true, however, in many cases, that some difficulty was experienced in uniting the verbal part of the maze with the motor part, the last few errors quite frequently being made in the motor part. Learning the last half in a motor manner, though, resulted in a saving in spite of this difficulty.

amount of verbalizing. There is one exception to this, however. One S of the kinæsthetic-visual group learned a maze the first day with a total of three errors and holds the lowest record on errors for a first-day maze. He was very steady, however, and in addition was extremely lucky on his first run, making only one error.

The best method of attack seemed to be a combination of the motor and verbal methods. Most Ss found it profitable to make two or three motor, exploratory runs to get the general swing of the maze, and then to memorize turns verbally from first to last. Not all found this out the first day, but most of them, particularly in the three-day groups, came to this conclusion before they had finished. More motor imagery, then, seemed to be used the first day than on succeeding days, there being a gradual shift toward verbal. Some Ss, however, made sudden shifts in imagery, doing the first maze in a purely motor manner, and the second largely in a verbal manner. As a rule, these were disgusted with their first day's record and after thinking the matter over, had come to the conclusion that it would be better to memorize the turns verbally. A few did all the mazes in a motor manner. Quite a number also used a certain amount of visual imagery in all the mazes; but it was nearly always secondary to some other form.

Groups 10, 16-*x* and 17-*x* offer important exceptions to this gradual change from motor to verbal imagery; but, as has already been pointed out, the mazes *N*, *W* and *E*, and particularly the first two, were of such a type that verbal imagery was not particularly efficacious. There were some other slight exceptions to this where the pattern of the repeated maze had been so well retained that the subjects spoke of knowing the maze without memorizing it part by part. This brings up the point that the Ss who had learned the first maze largely in a motor manner and had most of it greatly over-learned, as a rule gave better results the second day on the repeated maze than the verbalizers. This was because they began the repeated maze blindly, and the motor pattern, which had been built up the previous day, was given a chance

to function, whereas the verbalizers, particularly the extreme ones, began the repeated maze methodically, trying to memorize turns on the very first run. Verbal imagery, however, was apparently the best for all the mazes in this experiment with the above exceptions, and the fact that the Ss found this out is one of the reasons why the number of errors dropped off from day to day even though the mazes were dissimilar.

There seemed some evidence of a relation between intelligence and method of learning and a study was therefore made of this relation. Fifty-nine sophomores and juniors, out of some seventy who took part in the experiment, could be classified as being predominately verbal or motor in their method of attack. Thirty-three of these were predominatingly verbal and twenty-six predominatingly motor. The 33 averaged 28.7 errors on their first maze and the 26 averaged 63.7 errors.[21] The average raw score on the Scholastic Aptitude Test for the 33 was 583 and for the 26 was 513. In other words, the subjects who made the highest average on the Scholastic Aptitude Test, a highly verbal test, were verbal in their method of attack on the maze, and made the lowest or best average on the maze test. The verbalizers, however, who averaged only 70 points more on the aptitude test than the motorists, averaged less than half as many errors on the maze as the motorists. This comparison would seem to indicate that the difference in errors on the maze is out of proportion to the difference in points scored on the aptitude test, and that motorists are at a greater disadvantage on the maze than they are on these tests.

Summary and Conclusions

1. It seems evident from this study that a pattern like that of maze *M* is retained in memory and does function in the relearning of the same maze or a similar maze. This is particularly true when no other maze is given in between the

[21] C. J. Warden, The relative economy of various modes of attack in the mastery of a stylus maze, this Journal, 1924, 7, 243–275; R. W. Husband, Human learning on a four-section, elevated, finger maze, *J. Gen. Psychol.*, 1928, 1, 18. Warden and Husband found similar differences between the averages of subjects who use verbal and motor forms of imagery. Husband found an average of 10.7 trials for verbal subjects and 23 trials for motor subjects. Warden found an average of 32.2 trials for the former and an average of 123.9 trials for the latter.

first and the second maze. One S in Group 1 learned *M* the second time with a total of only one error, while one S in Group 2 relearned *M* with a total of two errors.

2. When another maze is put in between, however, the results are not so clear. The averages on the third maze can, as a rule, be accounted for largely in terms of practice-effect from maze-running in general, and not in terms of retention of specific patterns. There was some behavioristic evidence, however, in Group 13-*y* that patterns had been retained. In some cases this retention of patterns seemed to be an aid, and in others a handicap. Groups 16-*x* and 17-*x* offer evidence indicating that practice on an intervening maze, which is of a type different from the one being repeated, is less helpful than practice on a similar type of intervening maze. In fact, practice-effect in these groups seemed to be seriously interfered with by the introduction of mazes *E* and *W*, which are of a different type. Group 19 gives results on the third maze which are lower than those accounted for mainly on the basis of practice-effect. The intervening maze in this group, however, is quite similar to the repeated maze, and it seems that in this case retention-of-pattern from the second to the third maze is a factor in addition to that of general practice.

3. Frequently the pattern functions entirely non-consciously. The subject does not recognize the fact that he is relearning the same or a similar maze. Several Ss did not recognize the pattern, even though they made only one or two errors.

4. The results of Group 3, together with those of Groups 1 and 2, show that repeating a maze like *M* with the first horizontal move reversed the second day does not affect the aid derived from retention of pattern, but does affect recognition. Retention of pattern is not affected because all the moves except the first are the same, and all the points of choice are exactly the same. Recognition is probably affected because this slight alteration in pattern gives the maze an entirely different configuration.

5. A slightly greater alteration in pattern, however, causes an increase in errors the second day which is out of proportion

to the increase in objective dissimilarity. This is indicated by a comparison of the results of Group 4 with those of Group 3.

6. Maze *D*, when used as the second maze, seems to be about as difficult for Group 4 as for Group 7. This fact shows that the help derived from learning *M*, nine of whose moves are the same as nine of those of *D*, is about the same as that derived from learning *C*, which is the mirror-reversal of *D*.

7. Similarities in maze-patterns may, under some conditions, prove to be a handicap rather than an aid. This is shown by a comparison of the results of maze *H* in Groups 6 and 14. In Group 14 *H* is preceded by *A*, which has five successive moves about the middle of the maze which are identical with the same five moves in *H*; yet *H* proves to be more difficult to this group than it does to Group 6, which learned a very dissimilar maze preceding *H*.

8. Handedness is not a factor in maze-learning. This is evident both from a comparison of the results on the second maze in Groups 1 and 2 and from a comparison of those on the second maze in Groups 12 and 13.

9. Recognition has been found to be largely a question of mental set. It usually came suddenly and seemed similar to what has sometimes been called 'insight.'

10. Verbal imagery was found to be best in solving the T-type of maze, and motor imagery poorest. Ss using motor imagery made over twice as many errors as those using verbal imagery.

11. There was a pronounced tendency to change from motor to verbal imagery. Many made this change while learning the first maze, and the great majority of them, particularly in the three-day groups, had made the change before they finished the experiment.

12. A certain relationship was found to exist between average scores on a scholastic aptitude test, the average errors on mazes, and the types of imagery used. The subjects who were best on the aptitude test were also best on the mazes, and as a rule were predominately verbal in their method of attack.

(Manuscript received June 22, 1929)

THE EXPERIENTIAL FUSION OF WARMTH AND COLD IN HEAT

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Three experiments relating to the nature of heat have appeared within the last twelve years, those of Cutolo,[1] Alston,[2] and Burnett and Dallenbach.[3] All have made use of apparatus which actually touched the skin; so that the experience may have been affected by pressure resulting from a deforming contact with the skin. All three experimenters have held that heat includes a 'pressure' component. Working under the suspicion that this alleged component was due to the type of apparatus used, we have endeavored to produce heat without dermal contact.

Experiment I. Here we sought to obtain descriptions of heat, including its localization, the time taken for its arousal, and the limits of separation of the stimulated areas. Our apparatus was an adaptation of one described in the study of perceptions of softness and hardness by the senior writer of this article.[4] In its more recent form (see Fig. 1) the apparatus consists mainly of (1) a current of air flowing through copper tubes surrounded by ice and salt, for the production of cold; (2) a current of air flowing through a pyrex tube containing an electric coil, for the production of warmth; and (3) a current of air flowing through a narrow tube directly to the skin for the production of pressure. The temperature of the electric coil is controlled by means of a lamp-battery, and the coil is protected by asbestos coverings.

[1] F. Cutolo, Jr., A preliminary study of the psychology of heat, *Amer. J. Psychol.*, 1918, 29, 442–448.

[2] J. H. Alston, The spatial condition of the fusion of warmth and cold in heat, *ibid.*, 1920, 31, 303–312.

[3] N. C. Burnett & K. M. Dallenbach, The experience of heat, *ibid.*, 1927, 38, 418–431.

[4] A. H. Sullivan, The cutaneous perception of softness and hardness, this JOURNAL, 1927, 10, 447–462.

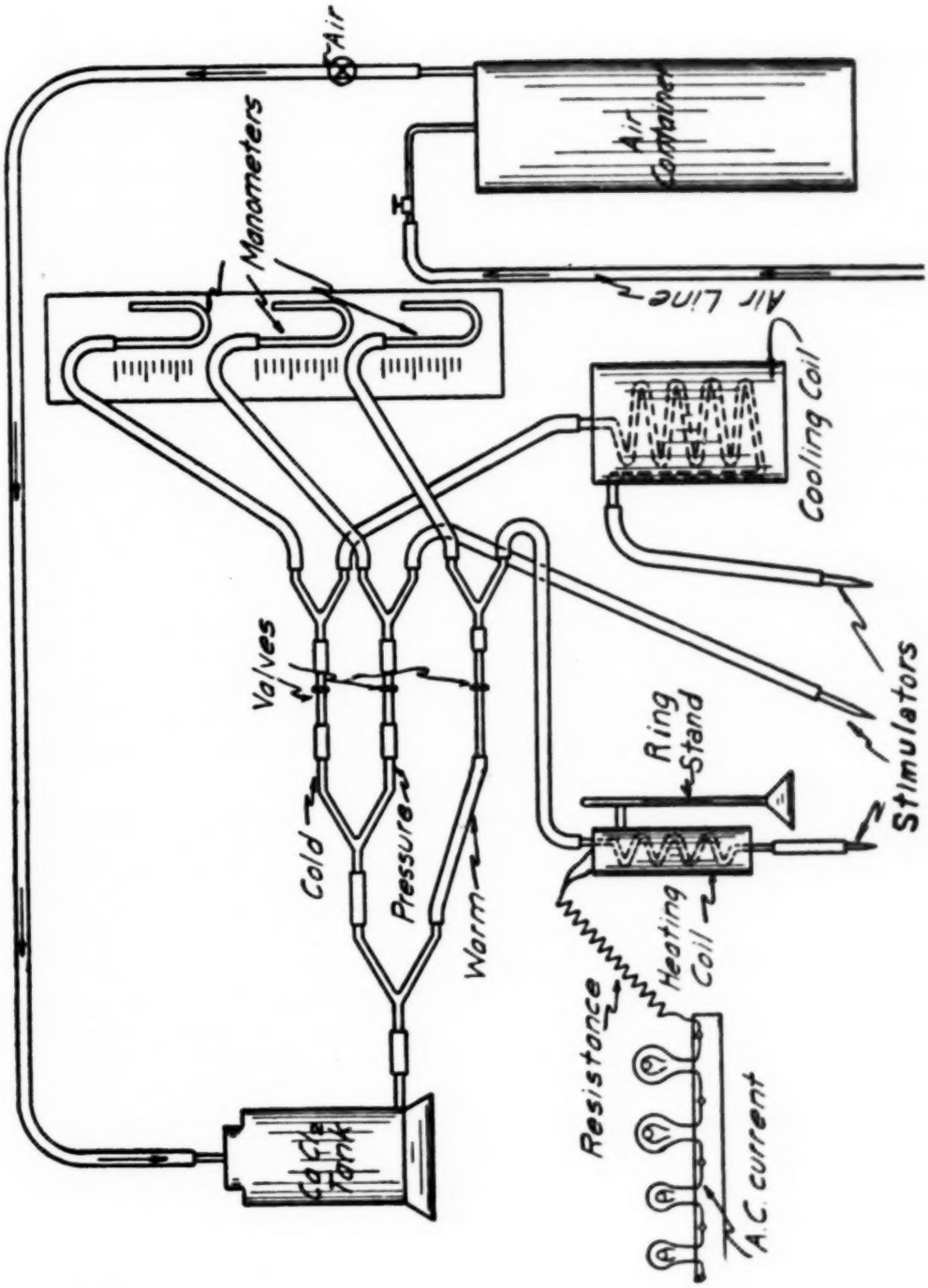
Air
Air Container
Manometers
Air Line
Cooling Coil
Valves
Cold
Pressure
Warm
Ring Stand
Stimulators
Resistance
Heating Coil
A.C. current
Water Tank

FIG. 1

The third part of the apparatus was not used in this experiment. The air is obtained from the University compressed-air system. Suitable manometers (unit of pressure .01 in. of water) connected with the air systems give an accurate measure of the air-blast at the skin. By reducing the air-pressure, we get reports of cold or warmth when a temperature spot is stimulated but no pressure from pressure spots. The air-pressure ranged between 0.4 and 0.6 in. on the manometric scale; the temperature of the cold stimulus was 17°–19°, and the temperature of the warm 38°–40° C. The room-temperature was nearly constant at 28.5° C.

Five cold and five warm spots were marked on the volar surface of the forearm at the beginning of the experimental hour. A warm and a cold spot were then stimulated simultaneously and the observer reported the experience. The spots were of varying degrees of separation, ranging from 1 cm to 15 cm. After the report the separation of the air-currents was recorded, the air-temperature read, and the air-pressure taken. The time-lag for the arousal of heat after the stimulation began was also kept.

The instructions read as follows: "After a ready signal, you will be given a cutaneous stimulus. Give a complete description of the experience."[5]

Table I records the number of 'heat' reports, and the time-lag for arousal. Table II shows the smallest, optimal, and largest degrees of separation of the spots at which heat was experienced.

TABLE I

REPORTS OF HEAT

Obs.	No. Exper.	No. Heat Reports	Time-lag for Heat (Sec) Shortest	Longest	Average
G.	34	33	6	15	9
S.	35	33	5	21	9
V.	33	32	5	19	10
C.	35	34	4	25	8
Total	137	132			

We found no correlation between the spatial separation of the air-currents and the length of time necessary to arouse heat.

[5] There were four observers: Professor E. A. Culler (C), Mr. Glanville (G), the senior author (S), all of the departmental staff, and the junior author (V).

TABLE II

Obs.	Separation of warm and cold air-currents: Smallest	Optimal	Largest
G	1.0	4.3	8.8
S	1.4	5.7	14.0
V	1.5	4.9	12.9
C	1.4	5.2	12.1

Localizations were sometimes mentioned by the observers. (See Table III.)

TABLE III

Obs.	No. Localizations	Midway between *W* and *C* Spots	Near *W* Spot
C	12	9	3
G	16	16	0
S	12	12	0
V	16	16	0

The following descriptions of heat by the various *O*s are typical.[6]

Obs.C. 1. "The first symptom of heat was something allied to a faint tingling, which became more and more pronounced, although not painful. There is a core to the heat, which is pretty well defined, localized quite definitely, and is the point of greatest intensity. This core extends down into the skin some distance; it is larger at the surface and tapers off below the surface, as though a plug had been driven into the skin. Around this core the intensity decreases and there is no particular contour to the boundary. The heat is less soft and filmy than the warmth and more so than the cold; it is intermediate between the two in texture."

2. "The experience started with warmth, then the *C* was brought in and I felt a coolness which came in surges. It took some time before the real heat quality came. It was localized about the place where the warmth had been, but it occupied a larger area than the warm. There is an undertone of sharp achiness, a beginning of pain, but it is hardly true pain. The heat differs from warmth in that warmth is milder, and the boiling, prickly character of heat is not in the warmth. There is a core to the heat, and there are little streamers radiating out from this core. The core seems to be fairly compact, but not so compact as cold; above the core there is a kind of diffuse, airy, light quality which is more like the billowing of the warmth, and this radiates out like a spray. The heat is a kind of combination of warmth and cold in texture."

Obs.G. 1. "I felt warmth first; it was quite diffuse and difficult to localize. Then cold came in; it was concentrated in one small spot. Then suddenly the warmth and cold disappeared and heat appeared. The core of the heat extended down deep into the skin; the periphery was superficial."

2. "Warmth, which is very weak and diffuse. Then cold, intense and concentrated. Then heat develops. It seems to be shaped like a cone with the base on the surface of the skin, and the column extending down into the skin. The column

[6] In the following pages, *C* and *W* will stand for the cold and warm thermal stimuli; while the terms cold, warmth, and heat will stand for experiential qualities.

is true heat, and superimposed on this there is a circle of warmth which is superficial and filmy. The column of heat is bright red in color; the circle of warmth is golden like sunlight."

3. "First I feel warmth, which is in two concentric circles. The outer circle is made up of weak warmth, the inner circle of intense warmth. Then cold comes in, and very soon the whole experience is on the verge of being sting-y. This is heat, and it goes down into the skin, and is shaped like a cone. The heat is about three times the size of the warmth which was first experienced."

Obs.S. 1. "First I feel cold; then warmth; and the cold seems to be fading away. Now both the warmth and the cold have disappeared and there is heat. The heat is much larger than warmth or cold, and it is tri-dimensional and solid and seems to form a long ridge between the warmth and the cold. The point of the ridge extends down into the skin and the broad part of the ridge is on the skin. It is much brighter than either warmth or cold, much more intense, and is coarser. Warmth is soft and fluffy; cold is hard and compact; heat is solid and bright and coarse, as if it had wrinkles in it."

2. "Warmth, soft and filmy; then cold, hard and compact. Now the two experiences have heaped up in the center to make heat, and warmth and cold as separate experiences have dropped out. I visualize the heat as being in the form of a long ridge, with the edge extending down into the skin. This ridge seems to cover all the area between the warmth and cold. Cold forms a little plug which extends down deep into the skin; warmth is almost superficial, being about as thick as velvet; heat is solid and deep at the center of the ridge, with a periphery around the ridge which is somewhat like warmth but coarser, like cheese cloth. Cold is bluish; warmth is tannish; heat is reddish with a suggestion of copper color in it."

3. "First I get warmth and then cold, and then almost immediately heat comes. It is a large *splash* of heat, reddish in color, and coarse, like cheese cloth, with a plug or center to it which extends down into the skin. The plug is compact and solid; the rest of the heat experience is on the surface of the skin and this part of it is coarse and thin. The heat has sting in it; it is almost like warmth *plus* sting, and yet neither warmth nor sting would ever cover as much area as the heat does, and neither warmth nor sting is ever solid and tri-dimensional. In these last respects heat is more like cold, although the core of the heat is not quite so compact as cold."

Obs.V. 1. "First I experienced warmth; then after a few seconds, heat. The core of the heat was tri-dimensional, conical-shaped, and compact, and it extended down into the skin quite a way. It was intense and sting-y. The boundary of the heat was on the surface of the skin, and was very much like a weak warmth, with an ill-defined boundary. The core of the heat was not so solid as the cold but it was much more so than warmth."

2. "First warmth and then cold, and then warmth disappeared and left cold, which was sharp and tri-dimensional, extending down into the skin. Then after a few seconds heat came; the peripheral part of it was on the surface of the skin, while the core, a solid pattern, extended down into the skin like a wedge. The heat possessed a slight sting, but it was not painful.

Results of Exper. I. (1) In 137 applications heat was reported 132 times. (2) The smallest degree of separation of the cold and warm spots in the production of heat averages 1.3 cm; the largest degree of separation averages 11.9 cm;

and the optimal separation averages 5.5 cm. (3) The length of time necessary for the production of heat after stimulation of a warm and cold spot averages 5 seconds. (4) Heat is usually localized between the warm and cold spots. (5) In all of our 132 descriptions of the experience of heat we have no reference to a pressure component. It is called tingling or sharp or prickling, but never 'pressury.' This is contrary to the results of the earlier experimenters and suggests that the previous experimenters found pressure in heat chiefly because tactual organs were excited by dermal depression. Heat is like warmth in that it has a flat, diffuse boundary and is mottled in texture. It is like cold in that it has a solid, tri-dimensional, compact core and a characteristic sting or tingling.

Experiment II. Here we wished to ascertain whether the warm and cold components were of equal saliency in the production of heat. By removing alternately the *W* and *C* stimulators, after the observers had reported the experience of heat, we hoped to discover what the effect of each component was. We used the three observers, C, S, and V. The method was the same as that used above, except that now we alternately removed and brought back the *W* and *C* stimulators and asked the observers to report on the successive experiences which followed this removal.

Table IV again shows the number of times heat was reported. For the relative saliency of the separate components, we refer to *O*s' reports.

TABLE IV

REPORTS OF HEAT

Obs.	No. Exper.	No. Heat Reports
S.	14	14
V.	18	17
C.	19	19
Total.	51	50

Obs.C. 1. "It begins with warmth which is rather intensive. Then cold comes in and there is a rivalry of the warmth and cold for a few seconds. Then there is a slow fusion into heat. The heat lies somewhat between the warm and cold areas. Heat resembles both warmth and cold; cold adds a kind of rough tingling to the warmth. When *W* is removed, the heat soon subsides leaving cool; when *W* returns the characteristic mottled, tingling heat returns. When *C* is removed, heat disap-

pears very quickly, immediately in fact; and so I get the impression that *C* is more important for heat than *W* is, even though I do seem to localize the heat nearer warmth than cold."

2. "I seem to get warmth and pain or sting without heat when only the warm spot is being stimulated. Then when *C* comes on, the heat slowly builds itself up. It seems to be localized about the place where the warmth had been; but it occupies a larger area than the warmth alone. When the *C* was removed there was left only a mild warmness over the area; the heat had disappeared. When *W* was removed the heat persisted for some time, so I got the impression that *C* had more of a controlling effect than *W* in the experience of heat."

Obs.S. 1. "Cold, which is hard, penetrating, and definite in boundary. Warmth, soft and diffuse. Then heat, which is sharp and compact at the center, but not so compact as the cold. When *C* is taken away and *W* remains, the heat disappears at once, leaving only a flat patch of warmth. The sharpness and the compactness of the heat leave with the *C*. When *W* is taken away and *C* remains, the heat persists for a few seconds, and just gradually fades away. It seems that the sharpness of the heat or its characteristic sting is given to it by the *C*."

2. "Warmth, soft and diffuse; then cold, hard and penetrating. These two experiences remain separate; there is a splash of warmth in one place and a bit of cold in another place. Now it gets hot, very hot right between the two areas, and the warmth and cold as separate experiences drop out. There is a core to the heat which is more intense than the periphery and which extends down some little way into the skin. The border of the heat is diffuse and thin and very coarse, with little strings or wrinkles in it. When *C* is taken away, the heat disappears at once; when *W* is taken away the heat remains for a few seconds."

Obs.V. 1. "Heat, fairly intense, with a weak warmth surrounding it. The core of the heat extended down into the skin and was a solid mass. When *C* was removed, the heat disappeared immediately, leaving a weak, diffuse warmth. Then *C* was brought back and heat came in again. Then *W* was removed, and a tingling, sting-y experience remained for a few seconds."

Results of Exper. II. (1) When *C* and *W* are removed alternately after heat has been experienced, the effects are unlike. The removal of *C* destroys heat at once; the removal of *W* does not. *C* seems to be more salient than *W*. (2) *C* is also more salient in heat in that it adds the characteristic tingle or sting, without which there is no true heat. *C* also furnishes compactness and tri-dimensionality. (3) *W* is necessary to the experience of heat in that it adds coarseness and stringiness and a characteristic flat boundary. (4) Heat may be said to be intermediate to warmth and cold, inasmuch as it partakes of the nature of both qualities. It is as if cold partially concentrates the warmth, making it tri-dimensional, compact, and tingling, while at the same time the warmth partially scatters the cold, making the resulting expe-

rience coarse, rough, and mottled, with a diffuse boundary. All of these effects taken together give us heat. (5) Of 50 reports of heat in Exper. II, we had not one reference to a pressure-like component.

Conclusions

1. When heat is aroused by stimulating warm and cold spots without contact with the skin, it is not intermediate between prick and pressure in quality. It seems that Cutolo, Alston, and Burnett and Dallenbach obtained the 'pressury' effect in heat because they actually touched the skin with the apparatus. Heat appears to be a psychological, as well as a physiological, fusion of warmth and cold. This conclusion is based on 182 descriptions of heat, given by four observers, in which there was no reference whatever to 'pressure' in heat.

2. The optimal separation of cold and warm air-currents in the production of heat is about 5 cm. Heat may be produced with cold and warm air-currents which are as close as 1 cm and as far apart as 14 cm. In this we agree with Alston.

3. The average time necessary for the arousal of heat after stimulation of a warm and a cold spot is 9 sec; but heat may appear in as short a time as 4, or in as long a time as 25 sec. There appears to be no correlation between the spatial separation of the organs excited and the length of time necessary for the arousal of the heat-experience. The length of time depends rather on the tuning of the receptors.

4. Heat is localized, as a rule, midway between the areas of warm and cold stimulation.

5. Heat is much larger in extent than either warmth or cold. At times it seems to cover the entire area between the two spots.

6. Cold is more salient than warmth in the fusion which results in the experience of heat, in that it adds the characteristic tingle or sting to the heat, and furnishes the compactness and tri-dimensionality which is so noticeable in the core of the heat. The removal of *C* from the fusion gives to the disappearing heat a very sudden and rapid *Abklingen*.

7. Warmth is necessary to the heat experience even though it is not as salient as cold. It adds coarseness and a stringy or mottled character, as well as a diffuse and flat boundary. The removal of *W* after heat is aroused does not immediately destroy the heat. The tingle of the *C* which is left seems to hold the heat-experience for a short time, giving to its disappearance a comparatively slow *Abklingen*.

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THE NEW PSYCHOLOGICAL LABORATORY AT NORTH CAROLINA

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Interest in psychology in America has reached the stage where the provision of adequate housing has become a widely recognized need which is increasingly manifested by the erection of new laboratory buildings devoted to this science on university and college campuses. In this situation it is certainly desirable that knowledge of the various new laboratories be disseminated, so that particular advantages of different plans may be made use of in further building. As there are certain points of special utility and convenience in the new building of the Department of Psychology at the University of North Carolina, I take the liberty of mentioning them.

In the spring of 1928 the Department moved into a building that had been gutted and entirely rebuilt according to the plans and specifications of the Department. For sentiment's sake, the outer brick walls of an historic building had been left standing, and had been lined with steel reinforced concrete, permitting the erection of floors and main partitions of the same durable and fireproof material. Sentimental considerations led also to the retaining of an assembly hall in the building for an old debating society not yet defunct, and the preservation of the historic brick walls made impossible the excavation of a desirable basement; but in all other respects the building is as designed by the senior members of the Department of Psychology [1] and is in exclusive use by them and their staff. The woodwork throughout was given a dull-rubbed wax finish, and all the furniture was finished to match.

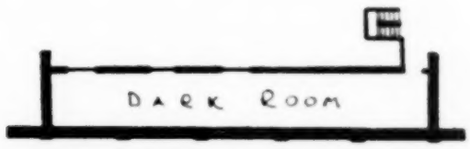
[1] In the designing, the writer was assisted by his colleagues, Dr. Harry W. Crane and Dr. English Bagby.

The building is piped throughout for gas, water, and sewer; and it is wired throughout for three electric systems, the AC campus-lighting supply at voltages of 110 and 220, and an inside wiring for DC of variable voltages furnished from a motor-generator located in the shop. These supplies are conveyed to every room in the building, making it possible to convert any one room from one use to another. Hoods for smoking kymograph drums are built in at four convenient places. An elevator is provided for heavy apparatus.

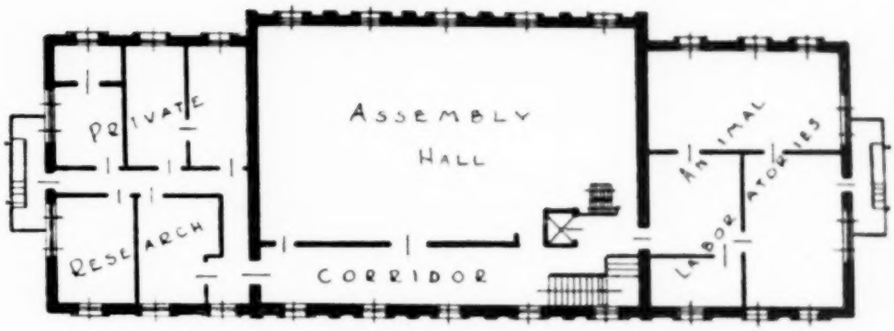
The first floor was intended primarily to furnish all the facilities necessary for elementary classes, including a lecture hall, a large elementary laboratory-room, and adjacent to the latter the offices for the laboratory instructors. The elementary laboratory was designed for the special needs of the beginning two-quarter course, which is scheduled for two 2-hour laboratory meetings weekly, in sections of twenty to thirty students each.[2] The room comfortably holds 16 tables, 27 in. x 48 in., at which students are seated in working pairs. Daylight from three sides and an abundance of wall-sockets are among the conveniences. The first floor also holds another class-room and other offices.

The second floor was intended mainly for the use of advanced classes. A large laboratory-room is convenient for the graduate training-course in experimental, and serves also as a general work-room. A class-room supplied with tables, 3 ft. x 10 ft., carrying individual locked drawers, conveniently serves many uses. A library holds the journals, current and bound, while the psychological books are stored at the general university library, they being less important in technical work. A special feature on this floor is the arrangement of two rooms for private clinical examination, with special furnishings and supplies, and a statistical room where are found comptometer, slide rules, etc., as well as supplies of test-materials. The shop is at present incompletely equipped, the Department sharing on a time-basis the use of a shop

[2] Notes on the organization of this course have appeared elsewhere. *Cf. Psychol. Rev.*, 1924, 31, 503–516 (which needs a revised statement); and *Psychol. Bull.*, 1927, 24, 80.



MEZZANINE FLOOR OVER CORRIDOR



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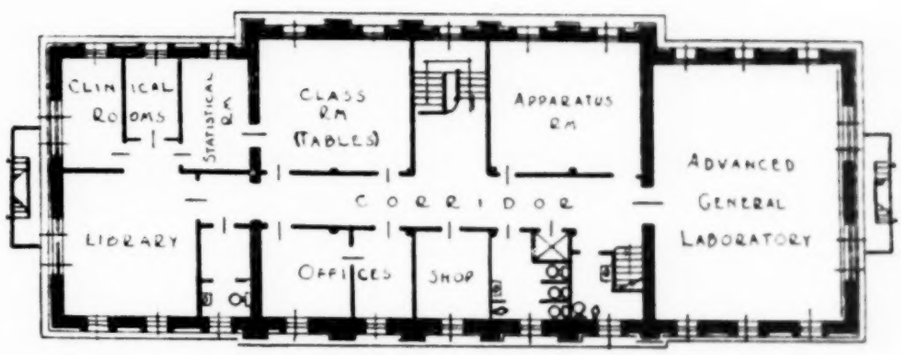
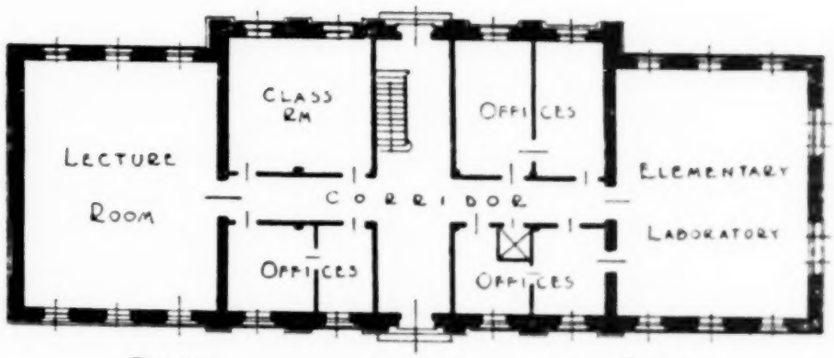


SECOND FLOOR



FIRST FLOOR PLAN

and technician in the Department of Physics in an adjoining building and having immediately available the resources of the University cabinet-shop also near at hand.

The third floor was set apart primarily for research. One wing provides a room for the white-rat colony with adjoining rooms in which investigations may be simultaneously pursued. The other wing is divided up into five rooms of varying shapes and door arrangements, in which graduate students and instructors may conduct their private researches. These research-rooms are protected from distractions from the rest of the building by a second outer door and by a distance of forty or more feet from the stairway and the animal rooms. (The central part of the third floor was retained for the historic debating society, whose small meetings once a week furnish no noticeable intrusion.) On a mezzanine above the corridor of the third floor is placed a dark room which is unique in size, being 54 ft. long, and making possible unusual experiments upon visual illusions of distance. No absolutely sound-proof room was constructed in the building, especially since no basement was possible; but the dark room, being on a floor to itself, is servicable in auditory experiments.

A detail of great convenience is the provision of master keys to all rooms in the building for janitor and for senior members of the staff, and of sub-master keys to the general laboratories, apparatus room, shop, class rooms, and library, for the advanced students.

A CORRECTION

In Fig. 1, which illustrates Dr. Jenkins' article on *Perceptual determinants in plane designs* in the February issue of this JOURNAL (1930, 13, 29), a confusion exists in the references to certain parts of the figure. The following changes should be made.

Page 30, lines 3, 4. *Omit* "of which Fig. 1, a is an example." Fig. 1, a is a design used in Series C; but it is a variant from Benary's forms.

Page 30, line 12. *For* "Fig. 1, *b*" *read* "Fig. 1, *a*." Figs. 1, *b* and 1, *c* are examples employed in Series D.

Page 31, line 7. *For* "Fig. 1, *c*" *read* "Figs. 1, *b* and 1, *c*."

Page 38, line 21. *For* "Fig. 1, *e*" *read* "Figs. 1, *e* and 1, *f*."